


Clinical surrogate markers for predicting metabolic syndrome in middle-aged and elderly Chinese

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Keywords

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ABSTRACT

Aims/Introduction: The present study evaluated the ability of lipid accumulation product (LAP), visceral adiposity index (VAI), and the product of triglycerides and glucose (TyG), three novel markers, in identifying metabolic syndrome (MetS) with different criteria in middle-aged and elderly Chinese.

Materials and Methods: During June 2012 to January 2013, 992 consecutive patients (age ≥ 40 years) were enrolled at Daping Hospital. The criteria of MetS were based on the International Diabetes Federation and the modified National Cholesterol Education Program's Adult Treatment Panel III. VAI, LAP and TyG were computed based on a published mathematical model.

Results: The prevalence of MetS was 42.8%. The receiver operating characteristic curve found LAP, VAI and TyG were positively related to MetS in both criteria. The optimal cut-offs of VAI, LAP and TyG for the modified National Cholesterol Education Program's Adult Treatment Panel III and International Diabetes Federation criteria were 2.015, 31.465 and 8.706, and 2.035, 37.99 and 8.697, respectively. After adjustment of potential confounding factors, VAI, LAP and TyG were significantly correlated with MetS in all criteria according to optimal cut-offs. For MetS, reliable predictive value was observed in different subgroups (age and sex). LAP showed the greatest area under the curve in MetS with the International Diabetes Federation definition (area under the curve 0.887, 95% confidence interval 0.852–0.922).

Conclusions: AP, VAI and TyG were reliable surrogate markers for identifying MetS in middle-aged and elderly Chinese. LAP could be a better parameter than VAI and TyG for predicting MetS in the present study.

INTRODUCTION

Metabolic syndrome (MetS) is a clustering of cardiometabolic abnormalities including central obesity, elevated triglyceride (TG) levels, elevated blood pressure, low high-density lipoprotein cholesterol (HDL-C) levels and hyperglycemia¹. MetS was correlated with cardiovascular disease, stroke and mortality^{2,3}. As the largest developing country in the world, China is experiencing an epidemic of MetS. One systematic review has shown a high prevalence of MetS (32.4%) in Mainland China⁴. Hence, as a result of the huge economic and society burden, MetS has

become a major challenge for the public healthcare system in China.

Lipid accumulation product (LAP) and visceral adiposity index (VAI) have been identified as two novel markers of visceral obesity^{5,6}. LAP combines TG and waist circumference (WC). VAI is evaluated by demographic (body mass index [BMI] and WC) as well as functional (HDL-C and TG) characteristics. In addition, the latest proposed marker is the product of triglycerides and glucose (TyG)^{7,8}. TyG combines two metabolic parameters – fasting plasma glucose (FPG) and TG⁷. With the high value of recognizing insulin resistance (IR), TyG is regarded a good marker for early identification of IR in individuals, especially in Chinese people⁹.

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VAI and LAP have been regarded as simple and novel clinical markers of MetS in previous studies^{10–19}. However, these markers could not meet different ethnic populations, and no previous research has investigated the diagnostic accuracy of VAI and LAP for MetS in Chinese. IR is a key component of MetS, and TyG, which is a simple measure reflecting IR, might help in identifying MetS. Furthermore, the relationship between TyG and MetS has not been investigated. To our knowledge, no research has estimated the efficacy of the three markers for predicting MetS. It is important to find simple and reliable indicators for easy diagnosis of patients with MetS in clinical settings. Hence, we investigated the clinical utility of three novel clinical markers, VAI, LAP and TyG, for MetS diagnosis in middle-aged and elderly Chinese.

METHODS

Study population

During June 2012 to January 2013, 1,137 consecutive patients with neurological symptoms or routine health examination in the Department of Neurology of Daping Hospital, Chongqing, China, were included in the present study. Inclusion criteria were long-term residents of local districts aged ≥ 40 years. A total of 145 individuals were excluded because of incomplete information about their physical examination or laboratory assessments. Finally, 992 participants were enrolled in analysis. This study was approved by the ethics committee of Daping Hospital, and was carried out in accordance with the Declaration of Helsinki. All patients provided consent forms.

Clinical assessment

Clinical data were collected through a detailed questionnaire containing patients' self-reported information and relevant medical records. Height (cm) and weight (kg) were quantified with patients wearing clothing without shoes. WC (cm) was measured using non-elastic tape at the umbilical level after normal expiration. The calculation of BMI (kg/m^2) was weight divided by the square of height. After 10 min of relaxing rest, the seated blood pressure of patients was determined using an aneroid sphygmomanometer. Fasting blood samples containing FPG, TG, total cholesterol, low-density lipoprotein cholesterol and HDL-C were determined by standard enzymatic techniques in a local clinical laboratory. Current smoking was defined as consuming one or more cigarette each day. Daily drinking was defined as alcohol consumption ≥ 8 g every week. The definition of diseases (diabetes mellitus, hypertension and previous stroke) was according to the International Classification of Diseases, 9th revision. Hypertension was diagnosed as follows: systolic blood pressure/diastolic blood pressure $>140/90$ mmHg, or using antihypertension drugs or previous diagnosis of hypertension. Diabetes mellitus was diagnosed as follows: FPG ≥ 7.0 mmol/L, self-report of diagnosis or use of diabetes medication. The diagnostic report of the physician about previous stroke was collected from each patient.

Definition of MetS

MetS was determined by the modified National Cholesterol Education Program's Adult Treatment Panel III (ATPIII)²⁰ and the International Diabetes Federation (IDF)^{21,22}. Both criteria (ATPIII and IDF) are widely used in China.

According to the definition of ATPIII, MetS needs at least three of five components: (i) central obesity (WC: men ≥ 90 cm, women ≥ 80 cm); (ii) elevated TG (TG ≥ 1.7 mmol/L); (iii) low HDL-C (HDL-C: men <1.03 mmol/L, women <1.29 mmol/L); (iv) elevated blood pressure (systolic blood pressure/diastolic blood pressure $\geq 130/85$ mmHg, or using anti-hypertension drugs); and (v) hyperglycemia (FPG ≥ 5.6 mmol/L or patients previously diagnosed with diabetes).

IDF is based on central obesity with two of four components: (i) elevated blood pressure; (ii) elevated TG; (iii) low HDL-C; and (iv) hyperglycemia.

Definition of clinical surrogate markers

VAI and LAP were calculated based on the sex-specific mathematical model formula. $\text{VAI} = (\text{WC}/[36.58 + (1.89 \times \text{BMI})]) \times (\text{TG}/0.81) \times (1.52/\text{HDL})$ for women, and $\text{VAI} = (\text{WC}/[39.68 + (1.88 \times \text{BMI})]) \times (\text{TG}/1.03) \times (1.31/\text{HDL})$ for men⁶. $\text{LAP} = (\text{WC} - 58) \times \text{TG}$ for women, and $\text{LAP} = (\text{WC} - 65) \times \text{TG}$ for men⁵. WC values below 65/58 cm in men/women were reassigned for 66.0/59.0 cm to avoid invalid data⁹. VAI and LAP, TG and HDL-C are presented as mmol/L. The index of TyG was calculated with the published formula^{7,8}: $\text{Ln}(\text{TG} [\text{mg}/\text{dL}] \times \text{FPG} (\text{mg}/\text{dL})/2)$.

Statistical analysis

Data were analyzed with SPSS 18.0 software (SPSS Inc., Chhicago, IL, USA). Categorical variables are expressed using percentages (%). Results were calculated with the χ^2 -test. Continuous variables were analyzed by Student's *t*-test with normal distribution. Results are shown as mean \pm standard deviation. For variables with skewed distribution, the results are described by median and interquartile range, and analyzed by the Mann–Whitney *U*-test.

The diagnostic ability for MetS in different criteria was defined by the area under the curve (AUC) in receiver operating characteristic analyses. In the subgroup, we further investigated the diagnostic value of the three markers stratified by sex and age. MedCalc version 11.4.2.0 (MedCalc Software bvba, Ostend, Belgium) was used to compare AUC values with the *Z*-statistic.

The optimal cut-off value was based on the greatest value of the Youden Index for identifying the risk of MetS. Multivariate logistic regression models were carried out to investigate whether LAP, VAI and TyG were significantly correlated to MetS in all criteria based on the assigned cut-off points. Results were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). A two-tailed value of $P < 0.05$ was regarded as statistical significance.

Table 1 | Comparison of clinical characteristics according to Adult Treatment Panel III criterion

Variables [†]	With MetS (n = 375)	Without MetS (n = 617)	P-value
Age (years)	65.67 ± 9.73	66.73 ± 10.5	0.103
Male, n (%)	137 (36.5)	339 (54.9)	<0.001
BMI (kg/m ²)	25.39 ± 3.43	22.47 ± 2.97	<0.001
Waist circumference (cm)	88.60 ± 8.22	79.82 ± 8.26	<0.001
Systolic blood pressure (mmHg)	139.82 ± 17.90	131.57 ± 16.47	<0.001
Diastolic blood pressure (mmHg)	82.72 ± 10.82	79.87 ± 9.89	<0.001
FBG (mmol/L)	5.63 (4.86–6.49)	4.90 (4.50–5.36)	<0.001
TC (mmol/L)	4.92 ± 1.14	4.71 ± 1.05	0.003
TG (mmol/L)	1.78 (1.20–2.41)	1.06 (0.80–1.39)	<0.001
HDL-C (mmol/L)	1.03 (0.89–1.18)	1.23 (1.04–1.46)	<0.001
LDL-C (mmol/L)	2.71 ± 0.77	2.51 ± 0.72	<0.001
Current smoking, n (%)	62 (16.5)	140 (22.7)	0.020
Daily drinking, n (%)	30 (8.0)	78 (12.6)	0.023
Hypertension, n (%)	284 (75.7)	228 (37.0)	<0.001
Diabetes mellitus, n (%)	122 (32.5)	53 (8.6)	<0.001
Previous stroke, n (%)	75 (20.0)	87 (14.1)	0.015
Components of MetS			
Elevated blood pressure, n (%)	316 (84.3)	274 (44.4)	<0.001
Hyperglycemia, n (%)	220 (58.7)	109 (17.7)	<0.001
Elevated TG, n (%)	207 (55.2)	70 (11.3)	<0.001
Low HDL-C, n (%)	307 (81.9)	205 (33.2)	<0.001
Central obesity, n (%)	288 (76.8)	123 (19.9)	<0.001
VAI	3.17 ± 1.84	1.48 ± 0.89	<0.001
LAP	53.47 ± 30.22	21.58 ± 15.04	<0.001
TyG	8.98 ± 0.57	8.35 ± 0.48	<0.001

[†]Results are expressed as mean ± standard deviation for variables with a normal distribution, as median and interquartile range for variables with a skewed distribution, or as number with percentage for categorical variables. ATPIII, Adult Treatment Panel III; BMI, body mass index; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LAP, lipid accumulation product; LDL-C, low-density lipoprotein cholesterol; MetS, metabolic syndrome; TC, total cholesterol; TG, triglyceride; TyG, the product of triglycerides and glucose; VAI, visceral adiposity index.

Table 2 | Predicted values and multivariate logistic regression of three clinical markers in different metabolic syndrome criteria

	Optimal cut-offs	Youden Index	Sensitivity	Specificity	PPV	NPV	OR (95% CI) [†]	P-value
MetS-ATPIII criterion								
VAI	2.015	0.528	0.725	0.802	0.984	0.146	15.19 (10.32–23.37)	<0.001
LAP	31.465	0.536	0.739	0.797	0.984	0.152	15.58 (10.61–22.86)	<0.001
TyG	8.706	0.509	0.715	0.794	0.983	0.140	11.58 (8.03–16.70)	<0.001
MetS-IDF criterion								
VAI	2.035	0.450	0.709	0.741	0.973	0.163	6.48 (4.66–9.03)	<0.001
LAP	37.99	0.568	0.732	0.845	0.984	0.189	14.17 (9.87–20.35)	<0.001
TyG	8.697	0.421	0.702	0.718	0.970	0.155	6.42 (4.61–8.93)	<0.001

[†]Adjusted for age, sex, current smoking, daily drinking, hypertension, diabetic mellitus and previous stroke. 95% CI, 95% confidence interval; ATPIII, Adult Treatment Panel III; IDF, International Diabetes Federation; LAP, Lipid accumulation product; OR, odds ratio; NPV, negative predictive value; PPV, positive predictive value; TyG, the product of triglycerides and glucose; VAI, visceral adiposity index.

RESULTS

Of 992 patients, 476 (48.0%) were men and 516 (52.0%) were women. The average age was 66.07 ± 9.9 years (range 40–93 years). Baseline characteristics are listed in Table 1 according to the MetS-ATPIII definition. The prevalence of

MetS was 42.8%. Patients with MetS showed higher WC, BMI, systolic blood pressure, diastolic blood pressure, FBG, total cholesterol, low-density lipoprotein cholesterol, TG, VAI, LAP and TyG, and lower HDL-C than those without MetS (*P* < 0.05). Additionally, participants with MetS had more

hypertension, diabetes mellitus and previous stroke, as well as lower frequencies of being male, current smoking and daily drinking ($P < 0.05$). All MetS components (hyperglycemia, elevated blood pressure, elevated TG, low HDL-C and central obesity) were higher in patients with MetS than those without MetS ($P < 0.001$).

The receiver–operator analysis confirmed the value of VAI, LAP and TyG in predicting MetS (Table 2). The optimal cut-offs of the MetS-ATPIII criterion were 2.015 for VAI (sensitivity 0.725, specificity 0.802, positive predictive value [PPV] 0.984, negative predictive value [NPV] 0.146, Youden Index 0.528), 31.465 for LAP (sensitivity 0.739, specificity 0.797, PPV

0.984, NPV 0.152, Youden Index 0.536) and 8.706 for TyG (sensitivity 0.715, specificity 0.794, PPV 0.983, NPV 0.140, Youden Index 0.509). In terms of MetS-IDFIII criterion, the optimal cut-off points were 2.035 for VAI (sensitivity 0.709, specificity 0.741, PPV 0.973, NPV 0.163, Youden Index 0.450), 37.99 for LAP (sensitivity 0.732, specificity 0.845, PPV 0.984, NPV 0.189 and Youden Index 0.568) and 8.697 for TyG (sensitivity 0.702, specificity 0.718, PPV 0.970, NPV 0.155, Youden Index 0.421).

According to optimal cut-offs, VAI, LAP and TyG were significantly correlated with MetS in all criteria. After adjustment of age, sex, current smoking, daily drinking, hypertension, diabetic mellitus and previous stroke, the ORs using ATPIII criterion were 15.19 (95% CI 10.32–23.37) for VAI, 15.58 (95% CI 10.61–22.86) for LAP and 11.58 (95% CI 8.03–16.70) for TyG. With regard to IDF criterion, the adjusted ORs were 6.48 (95% CI 4.66–9.03) for VAI, 14.17 (95% CI 9.87–20.35) for LAP and 6.42 (95% CI 4.61–8.93) for TyG (Table 2).

Figure 1 shows the values of VAI, LAP and TyG according to MetS components in the different sexes. MetS were defined according to ATPIII criterion. Notably, as the MetS components increased, the values of VAI, LAP and TyG increased accordingly in both sexes (P for trend < 0.001).

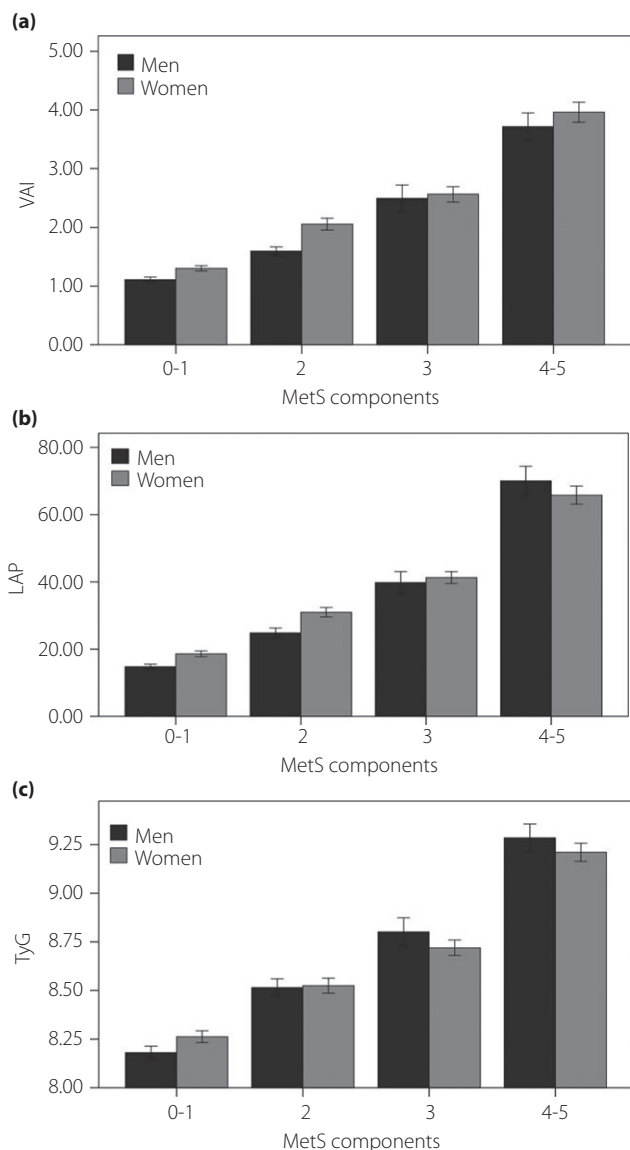


Figure 1 | The values of (a) visceral adiposity index (VAI), (b) lipid accumulation product (LAP) and (c) triglycerides and glucose (TyG) according to metabolic syndrome (MetS) components in both sexes.

Table 3 | Area under the curve of three clinical markers in different metabolic syndrome criteria

Variables	MetS-ATPIII criterion		MetS-IDF criterion	
	AUC (95% CI)	<i>P</i> -value	AUC (95% CI)	<i>P</i> -value
Overall				
VAI	0.830 (0.804–0.856)	0.008 [†]	0.783 (0.752–0.814)	<0.001 [†]
LAP	0.855 (0.831–0.878)	<0.001 [‡]	0.865 (0.841–0.889)	<0.001 [‡]
TyG	0.802 (0.774–0.831)	0.004 [§]	0.746 (0.712–0.779)	<0.001 [‡]
Men				
VAI	0.849 (0.812–0.886) [¶]	0.093 [†]	0.792 (0.739–0.844) [¶]	<0.001 [†]
LAP	0.872 (0.839–0.905) [¶]	<0.001 [‡]	0.887 (0.852–0.922) [¶]	<0.001 [‡]
TyG	0.812 (0.767–0.856) [¶]	0.007 [§]	0.751 (0.690–0.812)	0.016 [§]
Women				
VAI	0.803 (0.764–0.841)	0.046 [†]	0.759 (0.716–0.801)	<0.001 [†]
LAP	0.830 (0.795–0.865)	0.024 [‡]	0.844 (0.810–0.878)	<0.001 [‡]
TyG	0.795 (0.756–0.835)	0.569 [§]	0.744 (0.700–0.788)	0.304 [§]
Age ≥64 years				
VAI	0.839 (0.806–0.871)	0.140 [†]	0.783 (0.743–0.823)	<0.001 [†]
LAP	0.856 (0.826–0.886)	0.001 [‡]	0.867 (0.837–0.897)	<0.001 [‡]
TyG	0.810 (0.774–0.847)	0.020 [§]	0.743 (0.699–0.786)	0.003 [§]
Age <64 years				
VAI	0.828 (0.785–0.870)	0.045 [†]	0.790 (0.741–0.839)	<0.001 [†]
LAP	0.859 (0.821–0.896)	0.001 [‡]	0.867 (0.829–0.904)	<0.001 [‡]
TyG	0.804 (0.757–0.850)	0.143 [§]	0.758 (0.705–0.812) [¶]	0.084 [§]

[†]*P*-value between the area under the curve (AUC) value for visceral adiposity index (VAI) and that of lipid accumulation product (LAP). [‡]*P*-value between the AUC value for LAP and that of the product of triglycerides and glucose (TyG). [§]*P*-value between the AUC value for TyG and that of VAI. [¶]The highest AUCs. 95% CI 95% confidence interval; ATPIII, Adult Treatment Panel III; IDF, International Diabetes Federation.

Three markers were selected to assess MetS with AUC in different criteria (Table 3). We observed good predictive value of VAI, LAP and TyG for MetS according to the subgroups of age and sex (Figures 2 and 3; Table 3). In the subgroups, VAI showed the best diagnostic value for MetS in men (ATPIII criterion: AUC 0.849, 95% CI 0.812–0.886; IDF criterion: AUC 0.792, 95% CI 0.739–0.844). LAP also had the highest predictive performance in men than the other subgroups (ATPIII criterion: AUC 0.872, 95% CI 0.839–0.905; IDF criterion: AUC 0.887, 95% CI 0.852–0.922). As for TyG, the highest diagnostic accuracy was found in men with ATPIII criterion (AUC 0.812, 95% CI 0.767–0.856) and in the subgroup of age <64 years with IDF criterion (AUC 0.758, 95% CI 0.705–0.812). Compared with all subgroups in the three markers, LAP showed the best AUC for predicting MetS in the men subgroup with the IDF criterion (AUC 0.887, 95% CI 0.852–0.922).

DISCUSSION

The present study investigated the value of VAI, LAP and TyG, three novel clinical markers, in identifying MetS with different criteria in middle-aged and elderly Chinese. Our results

show that LAP, VAI and TyG have reliable predictive accuracy for diagnosis of MetS in both the ATPIII and IDF criteria. LAP might perform better than VAI and TyG for predicting MetS. This is the first report based on analyzing and comparing three novel markers for predicting MetS using different criteria, especially in the middle-aged and elderly Chinese population.

MetS has become a major public health burden in both Eastern and Western countries. Unlike Western populations, Asian populations have more abdominal fat distribution²³. Especially for Chinese people, because of the difference in cultural and lifestyle habits, this might result in a difference of abdominal fat distribution. MetS has been shown to be a strong predictive factor for cardiovascular³ and cerebrovascular diseases². Therefore, simple and effective markers for easy diagnosis of MetS would be essential for a clinical setting and screening evaluation.

In China, two definitions, ATPIII and IDF, have been extensively used for clinical practice or research of metabolic disturbance. The core components between the two criteria are similar for MetS^{20,22}. A major difference between the two criteria was the significance of central obesity. For the IDF criterion, central obesity is essential, as well as being a unique

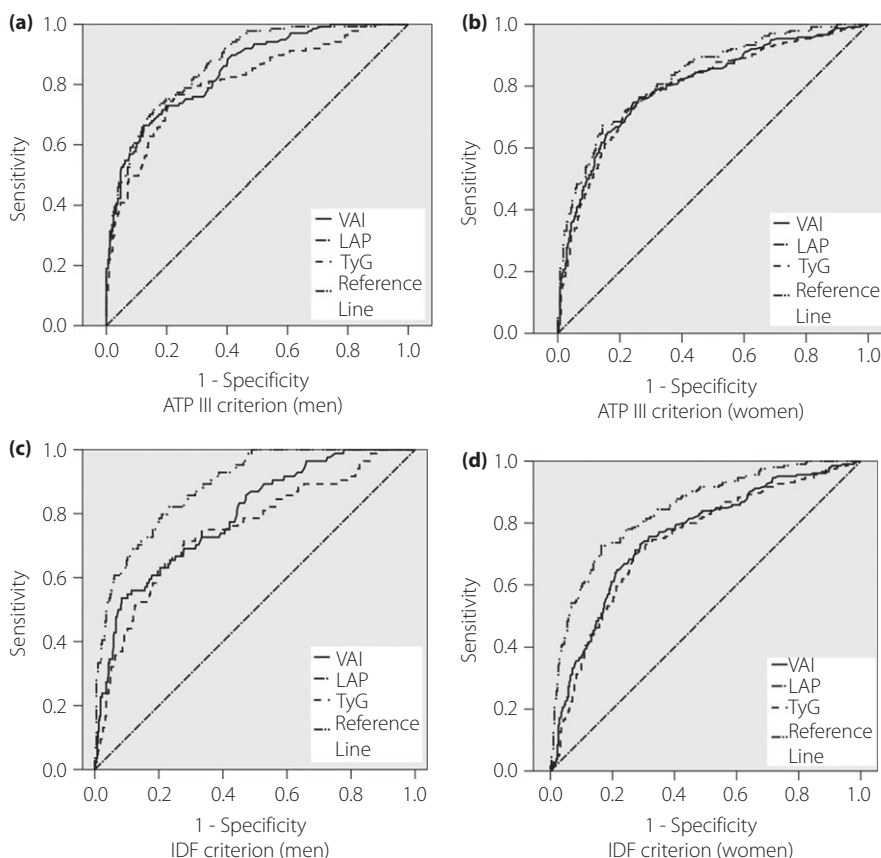


Figure 2 | Comparison of the diagnostic value of visceral adiposity index (VAI), lipid accumulation product (LAP) and triglycerides and glucose (TyG) in (a,c) men and (b,d) women in predicting metabolic syndrome using different criteria (modified National Cholesterol Education Program’s Adult Treatment Panel III [ATPIII] and International Diabetes Federation [IDF]).

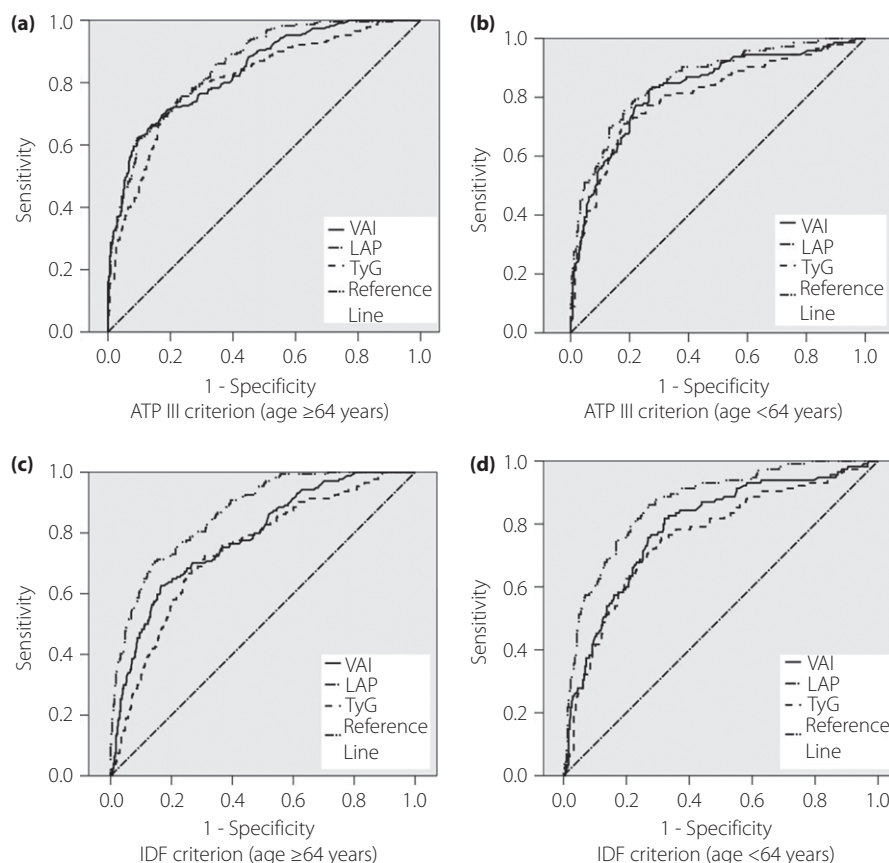


Figure 3 | Comparison of the diagnostic value of visceral adiposity index (VAI), lipid accumulation product (LAP) and triglycerides and glucose (TyG) in (a,c) age ≥ 64 years and (b,d) age < 64 years in predicting metabolic syndrome using different criteria (modified National Cholesterol Education Program's Adult Treatment Panel III [ATPIII] and International Diabetes Federation [IDF]).

prerequisite for MetS in Chinese populations²¹. Whereas for the ATPIII criterion, four other components are equally important as central obesity in MetS. In other words, the definition of ATPIII included more metabolic disorders²⁴.

As the marker of central obesity, LAP originated from the National Health and Nutrition Examination Survey III, and was widely used among Western populations⁵. Several reports have investigated the diagnostic power of LAP for MetS across different ethnic groups. One study showed that LAP had the ideal predictive value for MetS in 105 Chinese polycystic ovary syndrome patients (AUC 0.991, specificity 0.967, sensitivity 0.933)¹⁰. Chiang *et al.*¹¹ reported that LAP had the highest prediction accuracy (AUC 0.90) for Taiwanese ($n = 513$). The positive predictive performance was confirmed in 5,797 Iranian subjects (women: sensitivity 0.852, specificity 0.823; men: sensitivity 0.860, specificity 0.796)¹². In addition, similar results were also identified in Caucasian populations. Tellechea *et al.*¹³ documented that LAP was an ideal marker of MetS for 552 healthy Argentinian men (AUC 0.91). A recent study of 768 Spanish healthy adults showed that LAP had the greatest predictive

value in MetS-ATP III (AUC 91% for men, AUC 90% for women) and MetS-IDF (88% in both sexes)¹⁴.

VAI, first established by Amato *et al.*,⁶ incorporates four instructive measures (metabolic parameters: TG and HDL-C; anthropometric parameters: BMI and WC). As a good clinical marker of abdominal fat function, VAI was correlated to cardiometabolic diseases⁶. This important relationship between VAI and MetS has been observed in 361 Chinese individuals with obstructive sleep apnea (men: AUC 0.838; women: AUC 0.826)¹⁵. One study from Brazil¹⁶ with 221 older adults suggested that VAI was associated with MetS components. The same research carried out in 1,518 Peruvian adults¹⁷ showed that VAI could be an excellent indicator for MetS components. This close relationship was also found in 528 Caucasian individuals with suspected obstructive sleep apnea¹⁸.

To our knowledge, only one study has combined VAI and LAP for predicting the accuracy of MetS. Hasit Joshi *et al.*¹⁹ investigated 3,329 asymptomatic and healthy Gujarati Indian adults. The results reported that VAI and LAP had the best AUC (VAI: 0.856; LAP: 0.846) for MetS.

Consistent with other findings, we found that LAP and VAI had good predictive accuracy to identify MetS in the Chinese population. The association of LAP, VAI and MetS remained significant even after adjusting for several potential risk factors. However, our AUC values were lower than some other studies in predicting MetS. One possible explanation was the difference in participants. Most findings were based on healthy a population^{12–14,19}. Conversely, the present study included inpatients, which will pose some possible confounding factors. Additionally, the definition of MetS and sample size in the present study were also different from other populations. At last, anthropometric and racial differences could also affect our results.

TyG was first identified by Simental-Mendía *et al.*⁷ in healthy individuals. It is well-established that TyG is a simple marker for identifying IR with high sensitivity^{7,8}. TyG was more accurate for discriminating IR individuals in the Chinese population than VAI and LAP⁹. Lee *et al.*²⁵ validated this stronger association between TyG and developing diabetes in a Korean population. The same result was also confirmed based on a white European cohort²⁶.

As we all know, IR is closely related to MetS. In addition, a recent study²⁷ showed that the TyG index could be a credible indicator for predicting the risk of a cardiovascular event. Therefore, we further investigated this diagnostic power of TyG for MetS. The index of TyG increased in both sexes as MetS components increased. The results showed that TyG was significantly related to MetS in the two criteria according to the optimal cut-off (ATPIII criterion: OR 11.58, 95% CI 8.03–16.70; IDF criterion: OR 6.42, 95% CI 4.61–8.93). TyG was a reliable surrogate marker for identifying MetS (ATPIII criterion: AUC 0.802; IDF criterion AUC 0.746). Nevertheless, the present study showed lower accuracy of TyG for MetS, compared with other clinical markers in both sexes and age groups. It is mainly because TyG only combined FPG and TG. The absence of WC, a significant parameter for MetS, will decrease the accuracy of MetS.

The present study found that LAP was more accurate in the MetS-IDF criterion than the MetS-ATPIII criterion. On the contrary, VAI and TyG had a better ability to predict the MetS-ATPIII criterion compared with the MetS-IDF criterion. A possible explanation could be that LAP is consistent with the MetS-IDF criterion, which selected WC as an essential parameter. VAI includes more metabolic indicators, whereas WC is not considered in TyG components. All these factors will influence the predictive accuracy in different criteria of MetS.

The present study had some limitations. First, as a cross-sectional analysis with a relatively small sample size, future prospective designs are essential for appreciating the influence of these findings on features of MetS. Second, the study population was composed of Chinese people aged ≥ 40 years, and thus the results could not be generalized to different ethnic groups. Third, detailed information about long-term use of drugs, and education and health status were not documented in the present study, which could influence the results. Finally, insulin

resistance was not collected and analyzed in this study. Because of a lack of fasting insulin, it is difficult to obtain information about insulin resistance.

The present study showed that LAP, VAI and TyG are reliable surrogate markers for identifying MetS in middle-aged and elderly Chinese. LAP could be a better parameter than VAI and TyG for predicting MetS.

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DISCLOSURE

The authors declare no conflict of interest.

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