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Association between hyperuricemia and nontraditional adiposity indices

Xing Zhen Liu [1] · Hui Hua Li [2] · Shan Huang [2] · Dong Bao Zhao [3]

Abstract

Background The association between several novel adiposity indices and hyperuricemia is inconclusive. Therefore, we aimed to investigate this association so as to provide theoretical support for the management of hyperuricemia in overweight/obese individuals.

Methods A cross-sectional study was carried out among 174,698 adults. The values of body adiposity index (BAI), conicity index (CI), a body shape index (ABSI), body roundness index (BRI), visceral adiposity index (VAI), lipid accumulation product (LAP) index, and cardiometabolic index (CMI) were divided into four quartiles, and multivariate logistic analysis was used to analyze the association between them and hyperuricemia. Receiver operating characteristic curve and area under curve (AUC) were used to evaluate the power of predictions for hyperuricemia.

Results After adjusting for confounding variables, LAP and CMI exhibited stronger association with hyperuricemia than other indices. The odd ratio (OR) for hyperuricemia in the highest quartile of the LAP and CMI was 2.049 (CI 95% = 1.824–2.302) and 4.332 (CI 95% = 3.938–4.765). The AUC value of LAP was 0.632 (95% CI = 0.626–0.637), $p < 0.001$; and the AUC value of CMI was 0.687 (95% CI = 0.682–0.692), $p < 0.001$. The optimal cutoff values of LAP and CMI were 26.21 and 0.485, respectively.

Conclusions LAP and CMI, combination of WC and lipid parameters and reliable visceral adiposity indices, were strongly associated with hyperuricemia than other indices. So they could be potential monitoring indicators for hyperuricemia management in overweight/obese individuals.

Keywords Adiposity indices · Hyperuricemia · Obesity

Introduction

Hyperuricemia has been a major public health problem worldwide. In addition to contributing gout and nephrolithiasis, hyperuricemia is also related to diabetes, metabolic syndrome, and cardiovascular diseases [1–3]. Like other chronic metabolic diseases, hyperuricemia is the result of the interaction of genetic and extragenetic factors. Among these factors, obesity is considered to be a common risk factor for hyperuricemia. So some recommendations for the management of hyperuricemia and gout emphasized the beneficial effects of weight loss for hyperuricemia or gout patients with overweight/ obesity [4, 5].

Some traditional anthropometric indices, such as body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), and waist height ratio (WHtR), are commonly used as weight management indicators. But they also have some drawbacks. BMI can only identify the general obesity and has weak capacity to distinguish between muscle and fat accumulation [6, 7]. Although WC, WHR, and WHtR are considered to be specific alternatives to assess abdominal obesity [8], they cannot fully distinguish visceral fat, which is more closely related to hyperuricemia from subcutaneous fat [9].

To compensate for these deficiencies of traditional indices, several novel adiposity indices (body adiposity index (BAI),

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conicity index (CI), a body shape index (ABSI), body roundness index (BRI), visceral adiposity index (VAI), lipid accumulation product (LAP) index, and cardiometabolic index (CMI)) have been explored and proven to be more correlated with metabolic abnormality than traditional anthropometric indices [10, 11]. However, there are currently few comprehensive studies to assess the relationship between these nontraditional adiposity indices and hyperuricemia. Therefore, this large-scale cross-sectional study was designed to compare the relative strength of associations between hyperuricemia and these new indices, which may provide a theoretical basis for the precise management of overweight/obese individuals with hyperuricemia.

Methods

Participants

In China, many enterprises and institutions organize employees every year to conduct routine physical examination, which is used as a way to guarantee the health of employees and some kind of welfare. This cross-sectional study was based on the data of subjects who received routine physical examination between November 2015 and June 2018 in China's Yangtze River Delta region. There were a total of 174,698 adults with complete data in this study. Ethical approval was obtained from the local ethics committee.

Anthropometric and biochemical measurements

Height and weight were measured with participants barefoot and in light clothing on electronic scales. WC and hip circumference (HC) were measured by well-trained nurses. WC was obtained with an inelastic tape at the middle point of the lower costal rib and the top of the iliac crest. HC was obtained at the point of the maximum circumference of the buttocks.

Systolic and diastolic blood pressures (SBP/DBP) were measured using automatic blood pressure monitor (HEM-1000, OMRON). The blood samples of participants were collected after a minimum of 8 h of overnight fasting. Serum levels of fasting plasma glucose (FPG), plasma uric acid (UA), liver enzymes (alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and serum creatinine (Scr) were measured by a biochemical autoanalyzer.

Definitions

Hyperuricemia diagnosis for men and postmenopausal women was serum UA ≥ 420 μmol/L, and it was ≥ 350 μmol/L

in premenopausal women. The estimated glomerular filtration ratio (eGFR) was calculated using the Chronic Kidney Disease-Epidemiology Collaboration equation [12]. New adiposity indices were calculated as following formulas:

$$BAI = (HC\ (cm) \div Height^{1.5}\ (m)) - 18;\ CI = WC \div \left(0.109 \times \frac{weight\ (kg)}{height\ (cm)}\right);\ ABSI = WC \div \left(BMI^{\frac{2}{3}} \times height^{\frac{1}{2}}\right);$$

$$BRI = 364.2 - 365.5 \times \sqrt{1 - \left(\frac{WC}{2\pi}\right)^2 \div (0.5 \times height)^2};\ VAI$$

$$(males) = \left(\frac{WC}{39.68 + (1.88 \times BMI)}\right) \times \left(\frac{TG}{1.03}\right) \times \left(\frac{1.31}{HDLc}\right);\ VAI\ (females) = \left(\frac{WC}{36.58 + (1.89 \times BMI)}\right) \times \left(\frac{TG}{0.81}\right) \times \left(\frac{1.52}{HDLc}\right);\ LAP$$

$$(males) = (WC - 65) \times TG;\ LAP\ (females) = (WC - 58) \times TG;\ CMI = \frac{TG}{HDLc} \times WHtR.$$

Statistical analysis

Data are expressed as numbers (percentage) or means ± SD. Statistical analysis was performed using SPSS 18.0 (SPSS Inc.). Categorical variables were analyzed using the chi-squared test, and t test was used to test differences for continuous variables. Partial correlation and logistic regression analyses were applied to examine the association between new body fat distribution indices and hyperuricemia. Partial correlation was adjusted for age. When performing logistic regression analyses, the new body fat distribution indices were divided into four quartiles and the first quartile was used as a reference. Model 1 was with each new body fat distribution indices along; model 2 was adjusted for age and gender; and model 3 was adjusted for age, gender, traditional anthropometric indices, biochemical indicators, eGFR, smoking status, basic diseases, and medication (statins, diuretics, and hypoglycemic agents).

Receiver operating characteristic (ROC) analyses and the area under ROC curves (AUC) were then used to evaluate the predictive ability of the new adiposity indices for identifying hyperuricemia and to identify the optimal cutoff values of each new indices. The optimal cutoff value was determined by the maximized Youden index value (SEN + SPE-1). p value< 0.05 was considered statistically significant.

Results

The basic characteristics

Characteristics of 174,698 participants are summarized in Table 1. The prevalence of hyperuricemia was 20.7%. Compared with study population with normal UA level, individuals with hyperuricemia were more likely to be older, male, non-smokers, and with significantly higher biomarkers except DBP and eGFR. There were no significant statistical differences in traditional anthropometric indices except WC

Table 1 Basic characteristics of the participants

Variable	Total	Normal UA	High UA	p value
No., n (%)	174,698	138,457 (79.3)	36,241 (20.7)	
Age, year	45.0 ± 12.5	45.1 ± 12.5	44.7 ± 12.4	< 0.001
Male, n (%)	60.2%	59.8%	61.8%	< 0.001
Current smoking (%)	29.1%	30.1%	25.6%	< 0.001
Diabetes (%)	6.4%	6.6%	6.8%	0.426
Statin use (%)	0.23%	0.18%	0.2%	0.329
Antihypertensive treatment (%)	7.8%	7.8%	8.1%	0.061
BMI (kg/m^2)	23.6 ± 3.3	23.7 ± 3.3	23.5 ± 3.2	0.066
WC (cm)	79.4 ± 10.1	79.5 ± 10.1	79.3 ± 10.0	< 0.001
WHR	0.845 ± 0.072	0.845 ± 0.072	0.846 ± 0.072	0.437
WHtR	0.478 ± 0.055	0.478 ± 0.055	0.476 ± 0.053	0.513
SBP (mmHg)	124.5 ± 31.2	121.7 ± 15.1	123.4 ± 16.9	< 0.001
DBP (mmHg)	75.9 ± 11.5	75.9 ± 11.6	76.0 ± 11.5	0.259
FPG (mmol/L)	5.70 ± 1.18	5.62 ± 1.20	5.85 ± 1.08	< 0.001
TC (mmol/L)	4.75 ± 0.89	4.76 ± 0.87	4.91 ± 0.94	< 0.001
TG (mmol/L)	1.51 ± 1.27	1.35 ± 1.07	2.10 ± 1.73	< 0.001
HDLc (mmol/L)	1.49 ± 0.34	1.53 ± 0.34	1.36 ± 0.29	< 0.001
LDLc (mmol/L)	2.68 ± 0.76	2.66 ± 0.75	2.77 ± 0.79	< 0.001
UA (μmol/L)	339.8 ± 88.6	307.3 ± 62.6	463.9 ± 59.0	< 0.001
eGFR (mL/min/1.73 m^2)	69.8 ± 21.3	70.4 ± 22.5	69.8 ± 20.7	0.173
ALT (U/L)	27.3 ± 21.6	25.0 ± 19.1	36.2 ± 27.4	< 0.001
AST (U/L)	21.8 ± 10.7	21.0 ± 9.9	24.8 ± 12.7	< 0.001
ALP (U/L)	65.2 ± 18.6	64.5 ± 18.7	67.8 ± 17.9	< 0.001
BAI	25.8 ± 3.3	25.9 ± 3.38373	25.6 ± 3.14716	0.158
CI	18.6 ± 1.2	18.6 ± 1.3	18.6 ± 1.2	0.831
ABSI	0.075 ± 0.004	0.074 ± 0.004	0.075 ± 0.004	0.198
BRI	3.01 ± 1.00	3.02 ± 1.01	2.98 ± 0.97	< 0.001
VAI	1.85 ± 2.29	1.85 ± 2.34	1.87 ± 2.09	0.147
LAP	26.7 ± 7.8	24.1 ± 13.8	36.2 ± 17.39	< 0.001
CMI	0.606 ± 0.690	0.528 ± 0.584	0.867 ± 0.914	< 0.001

UA, plasma uric acid; *BMI*, body mass index; *WC*, waist circumference; *WHR*, waist to hip ratio; *WHtR*, waist height ratio; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; *FPG*, fasting plasma glucose; *TC*, total cholesterol; *TG*, triglyceride; *HDLc*, high-density lipoprotein cholesterol; *LDLc*, low-density lipoprotein cholesterol; *eGFR*, estimated glomerular filtration rate; *ALT*, alanine aminotransferase; *AST*, aspartate aminotransferase; *ALP*, alkaline phosphatase; *BAI*, body adiposity index; *CI*, conicity index; *ABSI*, a body shape index; *BRI*, body roundness index; *VAI*, visceral adiposity index; *LAP*, lipid accumulation product index; *CMI*, cardiometabolic index

($p < 0.001$) in the two groups of individuals. Among the seven new body fat distribution indices, only BRI, LAP, and CMI (all $p < 0.001$) were significantly higher in subjects with hyperuricemia.

The relationship between new indices and UA level

The partial correlation among new indices (BAI, CI, ABSI, BRI, VAI, LAP, CMI) and UA level is shown in Table 2. After controlling for age, only LAP and CMI ($r = 0.251, 0.276$, respectively; all $p < 0.001$) showed positive correlations with UA level. For men, high correlations were identified between LAP and CMI ($r = 0.262, 0.283$, respectively; all $p < 0.001$)

and the levels of UA; for women, LAP and CMI ($r = 0.235, 0.264$, respectively; all $p < 0.001$) showed relatively lower correlations with UA level than that of men.

The association between new indices and hyperuricemia

The logistic regression analysis results are shown in Table 3. After fully adjusting (model 3), only LAP and CMI but no other new indices were significantly associated with hyperuricemia. Compared with the first quartile, the other three quartiles of LAP and CMI were strongly associated with hyperuricemia. The ORs for hyperuricemia in the upper quartile of the

Table 2 Partial correlations coefficients between new body fat distribution indices and UA level

	Total		Men		Women	
	r	p values	r	p values	r	p values
BAI	− 0.003	0.544	0.001	0.943	− 0.005	0.485
CI	0.001	0.815	− 0.001	0.811	0.005	0.458
ABSI	0.006	0.164	0.006	0.271	0.005	0.421
BRI	0.004	0.327	0.004	0.444	0.004	0.601
VAI	0.005	0.231	0.009	0.074	− 0.001	0.898
LAP	0.251	< 0.001	0.262	< 0.001	0.235	< 0.001
CMI	0.276	< 0.001	0.283	< 0.001	0.264	< 0.001

All adjusted for age; *BAI*, body adiposity index; *CI*, conicity index; *ABSI*, a body shape index; *BRI*, body roundness index; *VAI*, visceral adiposity index; *LAP*, lipid accumulation product index; *CMI*, cardiometabolic index

LAP were 2.049 (CI 95% = 1.824–2.302) and $p < 0.001$; the ORs for hyperuricemia in the upper quartile of the CMI were 4.332(CI 95% = 3.938–4.765) and $p < 0.001$.

The AUC and optimal cutoff values of new indices

The ROC curves for the hyperuricemia incidence for new indices are shown in Fig. 1. Among them, only LAP and CMI were significant predictors for the risk of hyperuricemia. The ability and optimal cutoff values of LAP and CMI to predict hyperuricemia are summarized in Table 4. The AUC value of LAP was 0.632 (95% CI = 0.626–0.637), $p < 0.001$, and the cutoff value was 26.21 (Youden index = 20%); for men, the AUC value was 0.641 (95% CI = 0.634–0.647), $p < 0.001$, and the cutoff value was 26.02 (Youden index = 21.5%); for women, the AUC value was 0.624 (95% CI = 0.615–0.633), $p < 0.001$, and the cutoff value was 19.42 (Youden index = 19%). The AUC value of CMI was 0.687 (95% CI = 0.682–0.692), $p < 0.001$, and the cutoff value was 0.485 (Youden index = 27.8%); for men, the AUC value was 0.691 (95% CI = 0.685–0.698), $p < 0.001$, and the cutoff value was 0.497 (Youden index = 28.7%); for women, the AUC value was 0.682 (95% CI = 0.674–0.690), $p < 0.001$, and the cutoff value was 0.485 (Youden index = 26.6%).

Discussion

To our knowledge, this is the first large-scale cross-sectional study comparing the association between seven new adiposity indices (BAI, CI, ABSI, BRI, VAI, LAP, CMI) and hyperuricemia. The present study demonstrated that LAP and CMI, incorporating the WC and lipid parameters and reliable visceral adiposity indices, had stronger association with hyperuricemia than that of other indices. This result provides a new

idea for the comprehensive management of overweight/obese individuals with hyperuricemia.

The overall prevalence of hyperuricemia was 16.6% in Australia, 21% in the USA, and 25% in Irish [13–15]. With the rapid economic development and changes in the lifestyle, the incidence of hyperuricemia is also rapidly rising in China (from 1.4% in the 1980s, to 8.4% in the year 2009–2010) [16, 17]. A recent study reported that the incidence rate of hyperuricemia was 32.6% the southeast coastal region [18]. In this study, the prevalence of hyperuricemia was 20.7%. Although the prevalence of hyperuricemia varies significantly in different regions, hyperuricemia has been a public health burden.

The positive relationship of excess body fat, especially visceral fat, with hyperuricemia has been well established. In daily clinical practice, anthropometric indices are simple, convenient, and cost-effective assessment tool in the evaluation of body mass, size, and shape, which are used in screening of obesity and excess body fat. The relationship with hyperuricemia of traditional anthropometric markers such as BMI, WC, and WHtR has been explored [19, 20]. But these traditional indicators still have some shortcomings. In recent years, some new adiposity indices have been proposed and considered predictors of metabolic abnormality.

So far, there was only one study that explored the relationship between BAI and hyperuricemia, and showed a strong association of hyperuricemia with BAI [10]. Contrary to the existing research result, we did not find a significant association between them in the present study. The contradiction may result from the regional differences in subjects. BAI is an alternative to BMI in determining the general obesity [21], which has a weaker ability to distinguish fat distribution. So the association found between BAI and cardiovascular disease (CVD) or metabolic abnormality is inconsistent in different races, genders, and regions [22, 23].

The accumulated fat in the abdominal region is related to higher risks of obesity-related comorbidities [24]. Compared with BMI, WC can better describe abdominal adiposity. Three new anthropomorphic indices (CI, ABSI, and BRI), standardized WC for height or BMI, have been proposed as useful index of abdominal obesity. And the association between them and some metabolic diseases has been established [25, 26]. But no prior work has explored the relationship between them and hyperuricemia. In this study, the three new anthropomorphic indices were negatively associated with hyperuricemia. The mechanisms may be related to the characteristics of the WC itself. Although the WC can reflect the accumulation of fat in the abdomen, it has no ability to distinguish whether these abdominal fats are subcutaneous adipose tissue (SAT) or VAT which prospectively linked to hyperuricemia risk [9, 27]. This shortcoming of WC may exist in the new indicators that evolved from it and explain the negative association between them and hyperuricemia.

Table 3 Logistic regression analysis for association between new body fat distribution indices and hyperuricemia

	Q1	Q2		Q3		Q4	
		OR (95% C.I.)	*p* values	OR (95% C.I.)	*p* values	OR (95% C.I.)	*p* values
BAI	≤ 23.64	23.64–25.69		25.69–27.92		≥ 27.92	
Model 1	1.000 (ref)	1.0259 (0.990–1.061)	0.163	1.052 (1.016–1.088)	0.004	0.772 (0.744–0.800)	< 0.001
Model 2	1.000 (ref)	0.981 (0.924–1.042)	0.535	0.971 (0.909–1.039)	0.397	0.936 (0.862–1.015)	0.109
Model 3	1.000 (ref)	0.959 (0.900–1.022)	0.199	0.930 (0.863–1.001)	0.053	0.895 (0.815–0.984)	0.021
CI	≤ 17.76	17.76–18.55		18.55–19.40		≥ 19.40	
Model 1	1.000 (ref)	0.971 (0.938–1.006)	0.100	0.994 (0.960–1.029)	0.736	0.978 (0.944–1.013)	0.207
Model 2	1.000 (ref)	0.998 (0.938–1.062)	0.954	1.053 (0.981–1.132)	0.155	1.144 (1.045–1.252)	0.003
Model 3	1.000 (ref)	0.931 (0.870–0.995)	0.035	0.943 (0.869–1.025)	0.168	0.966 (0.866–1.077)	0.535
ABSI	≤ 0.071	0.071–0.074		0.074–0.077		≥ 0.077	
Model 1	1.000 (ref)	1.014 (0.979–1.050)	0.428	0.998 (0.964–1.034)	0.918	0.997 (0.963–1.033)	0.886
Model 2	1.000 (ref)	0.877 (0.820–0.938)	< 0.001	0.857 (0.788–0.932)	< 0.001	0.805 (0.722–0.897)	< 0.001
Model 3	1.000 (ref)	0.885 (0.824–0.950)	0.001	0.879 (0.803–0.963)	0.006	0.835 (0.741–0.941)	0.003
BRI	≤ 2.27	2.27–2.92		2.92–3.63		≥ 3.63	
Model 1	1.000 (ref)	0.956 (0.923–0.989)	0.010	0.949 (0.917–0.983)	0.003	0.880 (0.849–0.911)	< 0.001
Model 2	1.000 (ref)	0.815 (0.760–0.875)	< 0.001	0.724 (0.663–0.791)	< 0.001	0.658 (0.588–0.736)	< 0.001
Model 3	1.000 (ref)	1.287 (0.504–3.286)	0.598	1.162 (0.559–2.413)	0.688	1.083 (0.916–1.281)	0.350
VAI	≤ 0.83	0.83–1.31		1.31–2.13		≥ 2.13	
Model 1	1.000 (ref)	1.038 (0.995–1.084)	0.087	1.042 (0.998–1.088)	0.059	1.053 (1.009–1.099)	0.018
Model 2	1.000 (ref)	1.013 (0.958–1.072)	0.645	0.994 (0.939–1.053)	0.847	1.008 (0.949–1.070)	0.797
Model 3	1.000 (ref)	1.021 (0.964–1.080)	0.480	1.006 (0.949–1.066)	0.853	1.024 (0.963–1.088)	0.453
LAP	≤ 11.28	11.28–19.46		19.46–32.34		≥ 32.34	
Model 1	1.000 (ref)	1.171 (1.124–1.219)	< 0.001	1.673 (1.610–1.738)	< 0.001	3.170 (3.056–3.288)	< 0.001
Model 2	1.000 (ref)	1.195 (1.107–1.289)	< 0.001	1.422 (1.300–1.555)	< 0.001	1.846 (1.655–2.059)	< 0.001
Model 3	1.000 (ref)	1.247 (1.153–1.348)	< 0.001	1.537 (1.400–1.688)	< 0.001	2.049 (1.824–2.302)	< 0.001
CMI	≤ 0.269	0.269–0.429		0.429–0.694		≥ 0.694	
Model 1	1.000 (ref)	2.087 (1.971–2.210)	< 0.001	3.72 (3.529–3.932)	< 0.001	6.901 (6.548–7.274)	< 0.001
Model 2	1.000 (ref)	1.881 (1.743–2.031)	< 0.001	2.865 (2.641–3.109)	< 0.001	4.552 (4.150–4.993)	< 0.001
Model 3	1.000 (ref)	1.844 (1.708–1.992)	< 0.001	2.763 (2.543–3.001)	< 0.001	4.332 (3.938–4.765)	< 0.001

Model 1 was crude; model 2 was adjusted for age and gender; model 3 was adjusted for age, gender, traditional anthropometric indices, biochemical indicators, eGFR, smoking status, basic diseases, and medication (statins, diuretics, and hypoglycemic agents); *OR*, odds ratio; *C.I.*, confidence interval; *BAI*, body adiposity index; *CI*, conicity index; *ABSI*, a body shape index; *BRI*, body roundness index; *VAI*, visceral adiposity index; *LAP*, lipid accumulation product index; *CMI*, cardiometabolic index; *Q*, quartile

Compared with SAT, VAT has a stronger lipolysis and can secrete more pro-inflammatory factors, which contributes to more cardiovascular risk [28]. And some studies had proven the significant association between CT-measured visceral fat area (VFA) and hyperuricemia [29, 30]. The most accurate measurements of visceral adiposity are imaging techniques. But they are difficult to apply in clinical practice due to their price, equipment requirements, and radiation exposure. So, obtainable and accurate anthropometric indicators that can better capture VAT are needed to be explored. The new indicators of VAI, LAP, and CMI, combination of WC, and lipid parameters have been established to distinguish VAT from SAT. Previous studies have found a significant association between these new indicators and CVD risk or metabolic disease [22, 31, 32].

So far, there have been three studies on the correlation between VAI and hyperuricemia, and all found that the association of the VAI with hyperuricemia was significant [11, 33, 34]. But we found negative association between VAI and hyperuricemia in this study. These discrepancies may be related to the ethnic and regional differences of study samples. Until now, only one study has explored the association between hyperuricemia and LAP and CMI, and showed that LAP and CMI were responsible for increased risk of hyperuricemia [10]. In the present study, we also observed a strong association between hyperuricemia and LAP (OR = 2.049) and CMI (OR = 4.332). But the AUC values of the LAP and CMI were not high (0.632 and 0.687, respectively). After all, this is a cross-
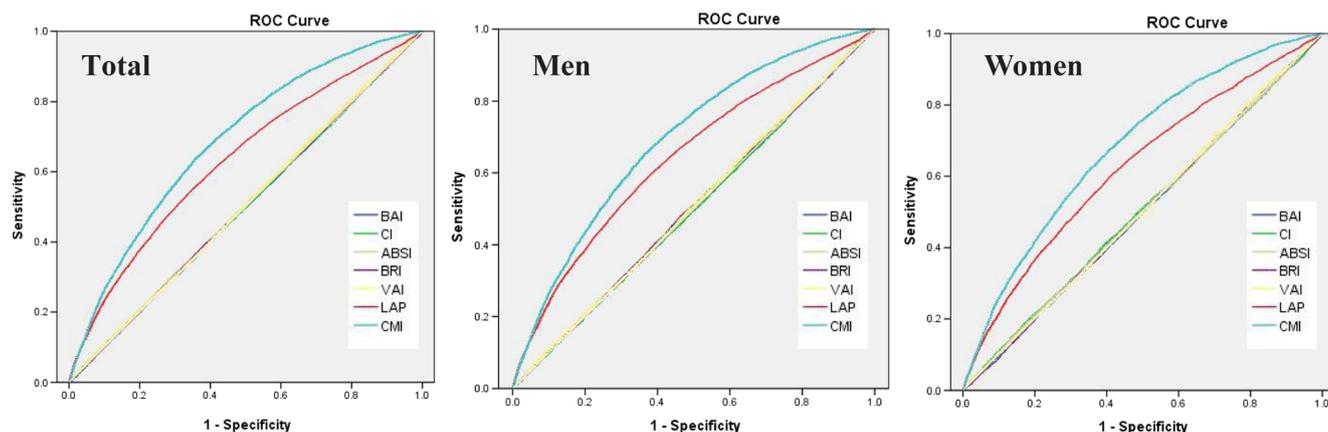
Fig. 1 Receiver operating characteristic (ROC) curves of BAI, CI, ABSI, BRI, VAI, LAP, and CMI to identify subjects with hyperuricemia. BAI, body adiposity index; CI, conicity index; ABSI, a body shape index; BRI, body roundness index; VAI, visceral adiposity index; LAP, lipid accumulation product index; CMI, cardiometabolic index

sectional study and the optimal cutoff points need further tests through longitudinal studies.

Several mechanisms have been proposed to explain the stronger association of hyperuricemia with LAP and CMI. To our knowledge, LAP and CMI are reliable visceral adiposity parameters that can assess VAT. So the mechanism must be discussed from the relationship between excess VAT and hyperuricemia. First, insulin resistance caused by excess VAT may affect renal excretion and reabsorption of uric acid [35]. Second, stronger lipolysis of VAT can increase the flow of free fatty acids (FFA) to the liver, which in turn affects the metabolism of purine [36]. Increased production of uric acid and decreased excretion are the key pathophysiological causes of hyperuricemia.

Weight loss from either surgery or diet is associated with a decrease in UA levels [37, 38]. So, several major guidelines recommended weight loss for gout or hyperuricemia management in overweight/obese individuals [39, 40]. However, there is currently no research to determine the optimal magnitude and intensity of weight loss [41].

The main reason is the heterogeneity of obesity caused by the difference in body fat distribution. For example, even though some Asians' BMI within the normal range, they may already have excess visceral fat and insulin resistance [42]. Therefore, the results of this study suggest that LAP and CMI (monitor of excess VAT) could be potential monitoring indicators for hyperuricemia management in overweight/obese individuals.

Our study has several limitations. Since this study was not a strict epidemiological investigation, we could not generalize the findings to the wider Chinese population. Secondly, this is only a cross-sectional study, so it cannot show a causal association between hyperuricemia and new body fat distribution indices.

In conclusion, our results showed that LAP and CMI, as hallmarks of excess VAT, were strongly positively associated with hyperuricemia. In clinical practice, LAP and CMI which are obtainable and cost-effective could be potential monitoring indicators for hyperuricemia management in overweight/obese individuals.

Table 4 The AUC with its 95% C.I. and cutoff values for predicting hyperuricemia by LAP and CMI

	AUC (95% C.I.)	p values	Cutoff	Sensitivity (%)	Specificity (%)	Youden index (%)	PPV (%)	NPV (%)	LR+	LR−
LAP										
Total	0.632 (0.626–0.637)	< 0.001	26.21	53.5	66.5	20	46.3	83.4	1.59	0.69
Men	0.641 (0.634–0.647)	< 0.001	26.02	59.5	62	21.5	31.3	83.9	1.55	0.65
Women	0.624 (0.615–0.633)	< 0.001	19.42	59.9	59.1	19	28.7	84.2	1.46	0.68
CMI										
Total	0.687 (0.682–0.692)	< 0.001	0.485	65.8	62	27.8	35.2	86	1.73	0.55
Men	0.691 (0.685–0.698)	< 0.001	0.497	66.2	62.5	28.7	35.6	85.8	1.76	0.54
Women	0.682 (0.674–0.690)	< 0.001	0.485	62.7	63.9	26.6	35.1	85.9	1.74	0.58

AUC, area under the receiver operating characteristic curve; *C.I.*, confidence interval; *LAP*, lipid accumulation product index; *CMI*, cardiometabolic index; *PPV*, positive predictive value; *NPV*, negative predictive value; *LR+*, positive likelihood ratio; *LR−*, negative likelihood ratio

Compliance with ethical standards

Ethical approval was obtained from the local ethics committee.

Disclosures None.

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