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The effects and predictive values of novel anthropometric parameters on uric acid levels and hyperuricemia in adults

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Novel anthropometric indices are more closely related to metabolic abnormalities than traditional anthropometric indices. Fewer studies have been conducted based on the relationship between novel anthropometric indicators and hyperuricemia. This study was to analyze the serum uric acid (SUA) levels of adults and the relationship between hyperuricemia and these new indicators in Su-Wuxi-Chang area of China, in order to provide a theoretical basis for the management of SUA levels in patients with hyperuricemia. A total of 14,834 adults were enrolled. The information of height, weight, waist circumference, lifestyle, fasting plasma glucose (FPG), lipids, and SUA were collected. The traditional obesity indices and novel anthropometric indices were calculated by formulas. Lipid accumulation product (LAP), triglyceride glucose (TyG) and body roundness index (BRI) are independent risk factors for hyperuricemia in both men and women ($P < 0.001$). In males, the predictive ability of LAP and TyG to the incidence of hyperuricemia were 0.694 and 0.661 in AUC area, respectively ($P < 0.001$) and which were 0.767 and 0.746 respectively in females ($P < 0.001$). In both men and women, the LAP and TyG indices were more predictive of hyperuricemia than the other indices ($P < 0.001$). The capacity of LAP and TyG indexes were better than other traditional anthropometric indexes in predicting hyperuricemia in this population. The predicted hyperuricemia ablity of LAP in both male and female better than other traditional and new anthropometric indicators.

Keywords Novel anthropometric parameters, Hyperuricemia, Obesity

Serum uric acid (SUA) is the end product of purine metabolism in body and independently associated with variety of chronic diseases[1–3]. Hyperuricemia is a metabolic disease due to disturbances in purine metabolism and elevated SUA concentrations[4]. With the improvement of living standards, the incidence of hyperuricemia is gradually increasing and there is a gradual trend of under-ageing[5]. The overall prevalence of hyperuricemia was 21% in the United States, 16.6% in Australia, and 25% in Ireland[6–8]. With rapid economic development and lifestyle changes, the incidence of hyperuricemia in China is also rising rapidly, from 1.4% in 1980s to 8.4% in 2009–2010[9,10]. The prevalence of hyperuricemia varies in different regions and hyperuricemia has become an important public health burden that seriously affects human health. Hyperuricemia is closely associated with many diseases such as diabetes and hypertension and SUA levels are an independent risk factor for cardiovascular events[11]. China currently has about 120 million patients with hyperuricemia and the annual growth rate is about 9.7%. Hyperuricemia has become the "fourth high" following hypertension, hyperlipidemia and hyperglycemia[12]. Novel anthropometric indices such as body adiposity index (BAI), a body shape index (ABSI), body roundness index (BRI), visceral adiposity index (VAI), lipid accumulation product (LAP) index, atherogenic index of plasma (AIP), and cardiometabolic index (CMI) are more closely related to metabolic abnormalities than traditional anthropometric indices such as body mass index (BMI), waist circumference (WC), and waist-to-body ratio (WHtR)[13,14]. Fewer studies have been conducted based on the relationship

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between novel anthropometric indicators and hyperuricemia. This study was to analyze the SUA levels of adults and the relationship between hyperuricemia and these new indicators in Su-Xi-Chang area of China, in order to provide a theoretical basis for the management of SUA levels in patients with hyperuricemia.

Methods

Study participants

This is a cross-sectional study. A total of 14,834 participants aged 18 years or older population who had health examination in Taihu Sanatorium of Jiangsu Province from March 2020-April 2021 were enrolled and they had resided locally for more than 5 years in Su-Xi-Chang area of China. Excluding those with previous myocardial infarction, personal history of malignant tumor, history of stroke, secondary hypertension, severe hepatic and renal insufficiency, those who had taken hormones, diuretics, allopurinol and other medications affecting SUA levels within six months before, and those who excluded incomplete data related to this study. A total of 9788 cases of males and 5046 cases of females were enrolled, with a median age of 50.61 ± 11.50 years. The study was approved by the Ethics Committee of our hospital (SGLL2020005) and the subjects signed an informed consent form. All methods were carried out in accordance with relevant guidelines and regulations (e.g. Helsinki guidelines).

Questionnaires

The survey was conducted by uniformly trained medical staff and included: age, smoking, alcohol consumption, exercise and history of previous diseases (hypertension, diabetes mellitus, coronary heart disease, stroke and other cardiovascular diseases and medication use).

The definition of smoking, drinking, diet and exercise

Smoking was defined as having smoked cigarettes in the 30 days prior to the survey; alcohol consumption was defined as more than 1 drink per week on average, regardless of the type of alcohol; healthy diet was defined as meeting 2 out of the following 3 criteria: consuming ≥ 5 servings of fruits and/or vegetables per day; ≥ 2 servings of fish (instead of red meat) per week, and 3) < 1500 mg of sodium per day; and physical activity was defined as exercising more than 3 times per week for a cumulative total of more than 90 min.

Calculation of indicators[15]

$BMI = Weight/Height^2$; $WHtR = WC/Height$;

$AIP = \log(TG\ [mmol/L] \times HDL\text{-}C\ [mmol/l])$;

$CMI = TG/HDL\text{-}C \times WHtR$;

LAP (females) $= TG(mmol/L) \times (WC[cm]-58)$;

LAP (males) $= TG(mmol/L) \times (WC[cm]-65)$;

$TyG = \ln[TG(mg/dl) \times FPG\ (mg/dl)/2]$;

$VAI(females) = WC/(36.58 + 1.89 \times BMI) \times (TG/0.81) \times (1.52/HDL\text{-}C)$;

$VAI(males) = WC/(39.68 + 1.88 \times BMI) \times (TG/1.03) \times (1.31/HDL\text{-}C)$;

$BRI = 364.2 - \{365.5 \times [1 - (WC/2\pi)^2/(0.5 \times height)^2]\}^{1/2}$;

$ABSI = WC(cm)/(height[cm])^{1/2} \times (BMI^2)^{1/3}$.

Biochemical tests

Before blood sampling, all subjects fasted for 8–12 h. About 5 mL of elbow venous blood was drawn on an empty stomach, and serum was separated for total cholesterol, low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), triacylglycerol (TG), FPG, and SUA. The diagnostic criterion for hyperuricemia was a fasting SUA level of > 420 μmol/L in males, and a SUA level of > 360 μmol/L in females[9].

Statistical processing

SPSS statistical software (version 18.0, IBM Corp, Armonk, NY, USA) was used to test the normal distribution and chi-square test of the measurement data. Measurement data conforming to the normal distribution were expressed as mean ± standard deviation (± s) and independent samples t-test was used for comparison between two groups; one-way analysis of variance (ANOVA) was used for comparison of the count data between multiple groups, and then LSD was used for comparison between two groups, and Tamhane′s method was used in case of chi-square test; non-normally distributed measurement data were expressed as median (P25, P75), and Mann-Whitney test was used for comparison between two groups. Normally distributed measures were expressed as median (IQR), and the Mann-Whitney test was used for comparisons between groups; the chi-square test was used for measurement data; the new anthropometric indices were categorized by quartiles, and one-way ANOVA was used to compare the levels of SUA across quartiles, and the trend of the chi-square test was used to analyze the results. To analyze changes in the incidence of hyperuricemia when novel anthropometric indices were classified in different quartiles. Partial correlation analysis was applied to analyze the correlation between the novel anthropometric indices and SUA levels in male and female populations, with model a unadjusted; model b adjusted for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet. logistic regression analysis was used to examine the relationship between the novel anthropometric indices and hyperuricemia, with model [a] unadjusted; model [b] adjusted for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet. The predictive ability of the new obesity indices for hyperuricemia was assessed using subject work characteristics (ROC) analysis and area under the ROC curve (AUC), and the optimal threshold value for each of the new indices was determined. The optimal cut-off value was determined using the maximum Yoden indicator value (SEN + SPE-1). The area under the ROC curve for LAP, TyG, and ABSI indices was calculated and compared using the DeLong method in MedCalc Statistical Software version 19.0.4 (MedCalc Software bvba,

Ostend, Belgium; https://www.medcalc.org; 2019)[16]. Two-tailed analyses were conducted and P value < 0.05 was considered statistically significant.

Results

Basic characteristics of the study sample stratified by sex status

A total of 14,834 participants were enrolled, with a mean age of 50.61 ± 11.50 years, 9,788 males and 5,046 females. The SUA levels of the subjects were 341.89 ± 84.18 μmol/L, which was higher in males (375.37 ± 74.68 μmol/L) than in females (276.93 ± 60.19 μmol/L) ($P < 0.01$). The prevalence of hyperuricemia in the subjects was 19.8%, which was higher in men (25.4%) than in women (9.0%) ($P < 0.001$). WC, SBP, DBP, FPG, TG, HDL, LDL, UA, BAI, CI, ABSI, BRI, VAI, LAP and CMI levels as well as the proportion of hyperuricemia, smoking, alcohol consumption, sensible diet, hypertension, and diabetes mellitus were higher in men than in women, and the difference was statistically significant ($P < 0.001$) (Table 1).

SUA levels changes in participants quartiles by new anthropometric indicator

All participants were stratified by sex and then grouped according to BAI, CI, ABSI, BRI, VAI, LAP, and CMI quartiles. Both males and females showed a gradual trend of increasing SUA levels in participants with increasing quartile groups for each indicator ($P < 0.001$). Trend chi-square analysis showed that all participants stratified by sex and grouped according to BAI, CI, ABSI, BRI, VAI, LAP, and CMI quartiles, both males and females showed a gradual increasing trend in the proportion of participants with hyperuricemia as the quartile grouping of each indicator increased ($P < 0.001$) (Tables 2 and 3; Fig. 1).

The correlation between novel anthropometric indicators and SUA levels

The novel anthropometric parameters BAI, CI, ABSI, BRI, VAI, LAP, and CMI correlated with SUA levels in both men and women and this correlation persisted after adjusting for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet, with correlation coefficients for SUA levels in men of 0.286, 0.198, 0.253, 0.191,

Variables	Total ($n = 14,834$)	Male ($n = 9788$)	Female ($n = 5046$)	T/Z/χ^2	P value
Age, mean (SD), years	50.6 (11.5)	50.7 (11.4)	50.4 (11.7)	− 1.57	0.116
BMI, mean (SD), kg/m^2	24.5 (3.0)	25.2 (2.9)	23.3 (2.9)	− 38.33	< 0.001
WC, mean (SD), cm	85 (10)	88 (8)	79 (8)	− 67.53	< 0.001
WHtR, mean (SD)	0.5 (0.05)	0.5 (0.05)	0.5 (0.05)	− 26.05	< 0.001
SBP, mean (SD), mmHg	126 (16)	129 (15)	120 (17)	− 33.27	< 0.001
DBP, mean (SD), mmHg	76 (11)	79 (10)	70 (10)	− 48.68	< 0.001
FPG, mean (SD), mmol/L	5.6 (1.3)	5.7 (1.4)	5.3 (0.9)	− 18.70	< 0.001
TC, mean (SD), mmol/L	4.8 (0.9)	4.8 (0.9)	4.8 (0.9)	2.41	0.016
TG, median (IQR), mmol/L	1.3 (0.9–2.0)	1.5 (1.0–2.3)	1.0 (0.7–1.5)	− 25.43	< 0.001
HDL, mean (SD), mmol/L	1.3 (0.3)	1.3 (0.3)	1.5 (0.4)	45.91	< 0.001
LDL, mean (SD), mmol/L	2.8 (0.7)	2.8 (0.7)	2.8 (0.7)	− 2.58	< 0.001
UA, mean (SD) (μmol/L)	342 (84)	375 (75)	277 (60)	− 81.04	< 0.001
Hyperuricemia (n, %)	2,944 (19.8)	2,489 (25.4)	455 (9.0)	563.78	< 0.001
Smoking (n, %)	4,745 (32.0)	4,723 (48.3)	22 (0.4)	4412.93	< 0.001
Drinking (n, %)	3,321 (22.4)	3,285 (33.6)	36 (0.7)	5312.65	< 0.001
Exercise (n, %)	1,012 (6.8)	566 (5.8)	446 (8.8)	450.32	< 0.001
Healthy Diet (n, %)	11,198 (75.5)	7,648 (78.1)	3,550 (70.4)	70.48	< 0.001
Diabetes mellitus (n, %)	1,335 (9.0)	1,086 (11.1)	249 (4.9)	154.30	< 0.001
Hypertension (n, %)	3,628 (24.5)	2,781 (28.4)	847 (16.8)	243.61	< 0.001
AIP, median (IQR)	0.00 (− 0.21–0.23)	0.09 (− 0.11–0.31)	− 0.17 (− 0.35–0.05)	− 45.64	< 0.001
CMI, median (IQR)	0.52 (0.30–0.89)	0.63 (0.39–1.07)	0.33 (0.21–0.56)	− 24.07	< 0.001
LAP, median (IQR)	29.28 (16.32–51.20)	35.04 (20.64–58.32)	20.03 (11.64–34.96)	− 24.80	< 0.001
VAI, median (IQR)	1.47 (0.92–2.43)	1.59 (1.00–2.65)	1.24 (0.80–2.05)	− 11.19	< 0.001
TyG, mean (SD)	8.70 (0.68)	8.86 (0.67)	8.40 (0.60)	− 41.14	< 0.001
ABSI, mean (SD)	0.78 (0.05)	0.79 (0.04)	0.76 (0.05)	− 28.17	< 0.001
BRI, mean (SD)	4.34 (0.65)	4.29 (0.60)	4.44 (0.72)	13.32	< 0.001

Table 1. Basic characteristics of the study sample stratified by sex status. Data are expressed as mean ± standard deviation or median (IQR) for continuous variables, and frequencies (percentages) for categorical variables. *BMI* body mass index, *WC* waist circumference, *WHtR* waist-to-height ratio, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *FPG* fasting plasma glucose, *TC* total cholesterol, *HDL* high density lipoprotein, *LDL* low-density lipoprotein, *UC* uric acid, *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

Variables	AIP	CMI	LAP	VAI	TyG	ABSI	BRI
Q1	345.30 ± 64.30	343.58 ± 63.03	341.79 ± 61.77	344.89 ± 63.96	347.57 ± 63.97	369.57 ± 71.62	356.02 ± 67.42
Q2	368.24 ± 70.24a	368.52 ± 70.37a	365.40 ± 68.32a	368.65 ± 70.15a	366.98 ± 67.98a	375.68 ± 72.01a	373.43 ± 72.37a
Q3	383.12 ± 72.18ab	383.50 ± 7 1.88ab	384.91 ± 72.18ab	382.78 ± 71.73ab	387.21 ± 72.01ab	379.11 ± 77.22a	381.36 ± 76.46ab
Q4	404.84 ± 78.44abc	405.88 ± 78.54abc	409.44 ± 78.40abc	405.17 ± 78.98abc	399.73 ± 82.69abc	377.12 ± 77.37a	390.81 ± 77.69abc
F	300.92	330.94	407.38	306.69	248.13	7.44	98.18
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 2. Changes in uric acid levels in male adults in quartiles of a new anthropometric indicator. Data are expressed as mean ± standard deviation or median (IQR) for continuous variables. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundnessindex. [a]Compared with Q1 group, $P < 0.05$; [b]compared with Q2 group, $P < 0.05$; [c]compared with Q3 group, $P < 0.05$.

Variables	AIP	CMI	LAP	VAI	TyG	ABSI	BRI
Q1	251.77 ± 49.13	250.53 ± 47.70	249.46 ± 47.82	251.11 ± 48.63	250.41 ± 48.07	267.66 ± 55.17	254.88 ± 48.23
Q2	266.18 ± 51.24[a]	264.93 ± 50.61[a]	263.00 ± 48.09[a]	266.54 ± 51.56[a]	264.54 ± 50.54[a]	275.27 ± 57.32[a]	268.97 ± 53.75[a]
Q3	280.86 ± 57.37[ab]	281.46 ± 57.53[ab]	282.91 ± 57.95[ab]	280.17 ± 57.16[ab]	281.92 ± 56.37[ab]	278.57 ± 61.12[a]	280.28 ± 59.23[ab]
Q4	308.96 ± 66.16[abc]	310.83 ± 65.88[abc]	312.43 ± 65.56[abc]	309.94 ± 65.82[abc]	310.89 ± 66.49[abc]	286.25 ± 65.22[abc]	303.77 ± 67.08[abc]
F	236.96	270.86	307.85	249.75	274.76	20.94	163.26
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 3. Changes in uric acid levels in female adults in quartiles of a new anthropometric indicator. Data are expressed as mean ± standard deviation or median (IQR) for continuous variables. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index. [a]Compared with Q1 group. [b]Compared with Q2 group. [c]Compared with Q3 group.

respectively. 0.293, 0.056, 0.174 ($P < 0.001$); correlation coefficients with SUA levels in women 0.274, 0.168, 0.229, 0.161, 0.271, 0.036, 0.167 ($P < 0.001$) (Table 4).

The effect of novel anthropometric indicators on hyperuricemia

In male participants, CMI, LAP, TyG, BRI were independent risk factors for participants' SUA levels, adjusting for SBP, DBP, FPG, smoking, alcohol consumption, exercise and diet, LAP, TyG, BRI were independent risk factors for SUA levels in the male population, and the risk of developing hyperuricemia in the LAP, TyG, and BRI Q4 group was respectively 4.96, 3.98, and 1.83 times ($P < 0.001$); among female participants, LAP, TyG, and BRI were independent risk factors for SUA levels in the participants, and after adjusting for age, SBP, DBP, FPG, smoking, alcohol, exercise, and diet, LAP, TyG, and BRI were independent risk factors for SUA levels in the female population, and the risk of hyperuricemia in the LAP, TyG, and BRI Q4 groups was 3.62, 5.52, and 2.91 times higher than that of the Q1 group, respectively ($P < 0.001$) (Table 5; Fig. 2).

Novel anthropometric indicators on hyperuricemia for prediction of hyperuricemia

The novel anthropometric indices LAP, TyG, and BRI had predictive value for hyperuricemia in both male and female participants. In women, LAP predicted hyperuricemia with an AUC of 0.767, sensitivity of 0.725, and specificity of 0.687 ($P < 0.001$); TyG predicted hyperuricemia with an AUC of 0.746, sensitivity of 0.666, and specificity of 0.720 ($P < 0.001$); BRI predicted hyperuricemia with an AUC of 0.716, sensitivity of 0.699 and specificity of 0.627 ($P < 0.001$). Traditional obesity indicators BMI, WC, and WHtR predicted hyperuricemia AUC of 0.720, 0.721, and 0.728, respectively ($P < 0.001$). In men, LAP predicted hyperuricemia AUC of 0.694, sensitivity of 0.629, and specificity of 0.659 ($P < 0.001$); TyG predicted hyperuricemia AUC of 0.661, sensitivity of 0.689, and specificity of 0.560 ($P < 0.001$); BRI predicted hyperuricemia AUC of 0.599, sensitivity of 0.742 and specificity of 0.406 ($P < 0.001$). Traditional obesity indicators BMI, WC, and WHtR predicted hyperuricemia AUC of 0.642, 0.638, and 0.626, respectively ($P < 0.001$) (Table 6).

Comparison of predictive ability of LAP, TyG index, WHtR and BIR for hyperuricemia

For the comparison of predictive ability for hyperuricemia in the male population, LAP was higher than TyG and WHtR, with an AUC area difference of 0.022 and 0.039 ($P < 0.001$), respectively, and the difference was not statistically significant when compared to TyG index and WHtR; in the female population, LAP was higher for the prediction of hyperuricemia in this population compared to TyG and BMI, with an AUC difference of 0.033 and 0.052 ($P < 0.001$), and the difference in predictive ability was not statistically significant compared to TyG and WHtR. In both men and women, LAP had a higher predictive ability for hyperuricemia than other obesity indicators in this population ($P < 0.001$), with TyG having the next highest predictive ability (Table 7).

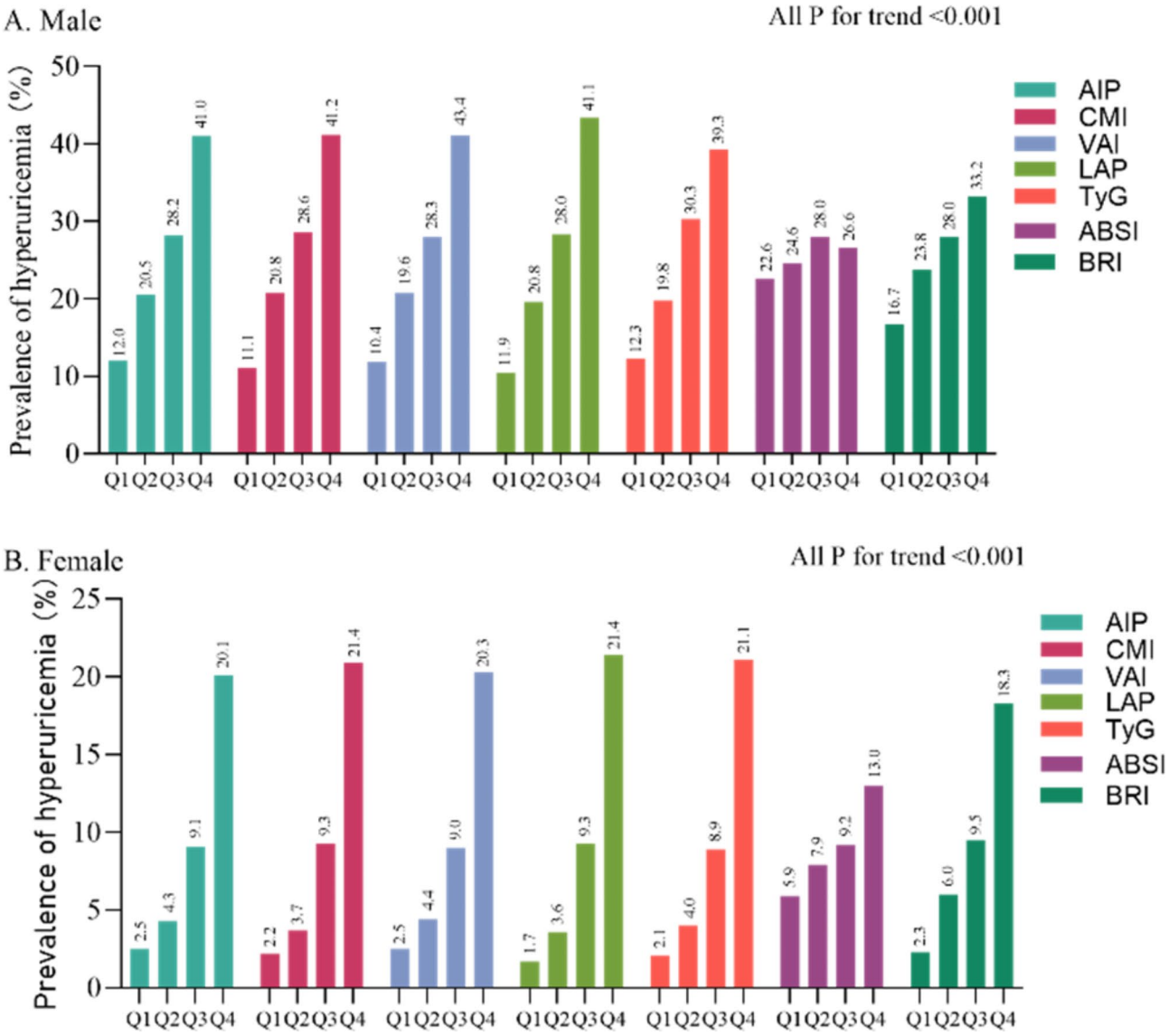

Fig. 1. Analysis of the percentage of hyperuricemia in quartiles of a new anthropometric indicator. Data are expressed as frequencies (percentages) for categorical variables. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG* index-triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

Discussion

The prevalence of hyperuricemia was 25% in men aged 40–74 years in Shanghai and 14.9% in Nanjing, with a higher prevalence in men than in women[5,10]. This study showed that the prevalence of hyperuricemia in the adult population was 19.8%, 25.4% in males and 9.0% in females, which was lower than Shanghai and similar to Nanjing. Nanjing, Shanghai, and Suxi-Xi-Chang area belong to the Yangtze River Delta plain and the Taihu River system in China. Local resident have similar diets and cultures. Shanghai is the economic center of China, with an economic aggregate equivalent to two or three times that of Nanjing, and Suxi-Xi-Chang area is representative among these several cities. The prevalence of hyperuricemia varies among populations in different regions of China, possibly due to differences in the level of economic and lifestyles. Interestingly, in addition to its association with chronic disease, hyperuricemia may also increase mortality, especially in women over 50 years of age[17]. Hyperuricemia has become an important public health burden that deserves more attention.

Previous studies have used traditional anthropometric indices such as BMI, WC, and WHtR, and the positive correlation between excess body fat accumulation and hyperuricemia has been well established. Kim et al.[18] demonstrated that the prevalence of hyperuricemia increased with increasing BMI, and that overweight people accounted for 61.7% of the patients with hyperuricemia. A cross-sectional study of 1426 participants in Mongolia, China, showed that the prevalence of hyperuricemia and SUA levels were most strongly correlated with WC and triglycerides[19]. BMI and alcohol consumption were associated with SUA levels with a significant interaction. BMI preceded hyperuricemia and the latter partially mediated the relationship between BMI and hypertension,

Variables	Male				Female			
	Model a		Model b		Model a		Model b	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
AIP	0.31	< 0.001	0.29	< 0.001	0.36	< 0.001	0.27	< 0.001
CMI	0.32	< 0.001	0.20	< 0.001	0.24	< 0.001	0.17	< 0.001
LAP	0.36	< 0.001	0.25	< 0.001	0.33	< 0.001	0.23	< 0.001
VAI	0.31	< 0.001	0.19	< 0.001	0.23	< 0.001	0.16	< 0.001
TyG	0.28	< 0.001	0.29	< 0.001	0.37	< 0.001	0.27	< 0.001
ABSI	0.04	< 0.001	0.06	< 0.001	0.12	< 0.001	0.04	0.011
BRI	0.19	< 0.001	0.17	< 0.001	0.31	< 0.001	0.17	< 0.001

Table 4. Analysis of the biased correlation between novel anthropometric indicators and uric acid levels in adults. Model a unadjusted; model b adjusted for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

Variables		Q1	Q2		Q3		Q4	
			OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
AIP	Male model a	1	1.16 (0.79–1.69)	0.457	1.54 (0.94–2.52)	0.089	2.00 (1.07–3.72)	0.029
CMI		1	1.61 (1.10–2.35)	0.015	1.77 (1.08–2.92)	0.024	1.59 (0.87–2.91)	0.133
LAP		1	1.80 (1.48–2.20)	< 0.001	2.74 (2.16–3.46)	< 0.001	4.96 (3.80–6.48)	< 0.001
VAI		1	0.71 (0.45–1.10)	0.123	0.48 (0.27–0.84)	0.011	0.47 (0.23–0.94)	0.034
TyG		1	1.64 (1.40–1.92)	< 0.001	2.77 (2.38–3.22)	< 0.001	3.98 (3.43–4.62)	< 0.001
ABSI		1	0.91 (0.79–1.05)	0.185	0.99 (0.86–1.14)	0.852	0.84 (0.73–0.98)	0.022
BRI		1	1.30 (1.12–1.51)	< 0.001	1.50 (1.29–1.75)	< 0.001	1.83 (1.57–2.13)	< 0.001
AIP	Male model b	1	1.10 (0.75–1.62)	0.636	1.41 (0.88–2.42)	0.138	1.82 (0.95–3.37)	0.071
CMI		1	1.72 (1.16–2.54)	0.007	1.84 (1.11–3.06)	0.019	1.69 (0.91–3.13)	0.094
LAP		1	1.75 (1.43–2.14)	< 0.001	2.60 (2.03–3.29)	< 0.001	4.58 (3.46–6.06)	< 0.001
VAI		1	0.70 (0.45–1.11)	0.128	0.50 (0.28–0.89)	0.019	0.53 (0.26–1.09)	0.082
TyG		1	1.62 (1.38–1.91)	< 0.001	2.83 (2.42–3.31)	< 0.001	4.65 (3.95–5.48)	< 0.001
ABSI		1	0.94 (0.81–1.08)	0.388	1.04 (0.90–1.21)	0.605	0.98 (0.84–1.15)	0.853
BRI		1	1.30 (1.12–1.52)	0.001	1.49 (1.28–1.75)	< 0.001	1.85 (1.57–2.19)	< 0.001
AIP	Female model a	1	0.95 (0.33–2.73)	0.919	1.02 (0.29–3.59)	0.979	1.14 (0.27–4.71)	0.861
CMI		1	1.49 (0.52–4.24)	0.455	3.59 (1.01–12.82)	0.049	5.57 (1.37–22.71)	0.017
LAP		1	2.02 (1.12–3.65)	0.019	4.20 (2.19–8.05)	< 0.001	7.85 (3.93–15.69)	< 0.001
VAI		1	0.64 (0.19–2.15)	0.475	0.35 (0.09–1.44)	0.145	0.33 (0.07–1.58)	0.164
TyG		1	1.58 (0.98–2.56)	0.060	3.11 (2.01–4.81)	< 0.001	7.38 (4.85–11.23)	< 0.001
ABSI		1	0.86 (0.62–1.20)	0.369	0.81 (0.58–1.13)	0.210	0.88 (0.63–1.22)	0.447
BRI		1	2.13 (1.36–3.34)	< 0.001	2.84 (1.82–4.42)	< 0.001	4.89 (3.14–7.63)	< 0.001
AIP	Female model b	1	1.10 (0.37–3.23)	0.869	1.35 (0.37–4.87)	0.651	1.63 (0.38–6.94)	0.507
CMI		1	1.21 (0.85–2.77)	0.717	2.37 (0.66–8.48)	0.188	3.47 (0.84–14.41)	0.086
LAP		1	1.54 (0.85–2.77)	0.153	2.49 (1.30–4.79)	0.006	3.62 (1.79–7.32)	< 0.001
VAI		1	0.72 (0.21–2.48)	0.601	0.47 (0.11-2.00)	0.306	0.45 (0.09–2.24)	0.326
TyG		1	1.35 (0.83–2.19)	0.228	2.52 (1.62–3.92)	< 0.001	5.52 (3.60–8.47)	< 0.001
ABSI		1	0.85 (0.61–1.19)	0.342	0.84 (0.60–1.17)	0.305	0.85 (0.60–1.19)	0.343
BRI		1	1.84 (1.17–2.90)	0.008	2.11 (1.34–3.33)	0.001	2.91 (1.82–4.66)	< 0.001

Table 5. Logistic regression analysis of the effect of novel anthropometric indicators on hyperuricemia. Model a unadjusted; model b adjusted for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

independent of behavioral and other metabolic factors[20]. The relationship between hyperuricemia and BMI is bidirectional, SUA and its production can be involved in the progressive reduction in tissue insulin sensitivity, increased blood pressure and atherogenic dyslipidemia that can largely contribute to the excess in the risk of cardiovascular disease[21]. Higher BMI may increase SUA levels through renal impairment, causing a decrease

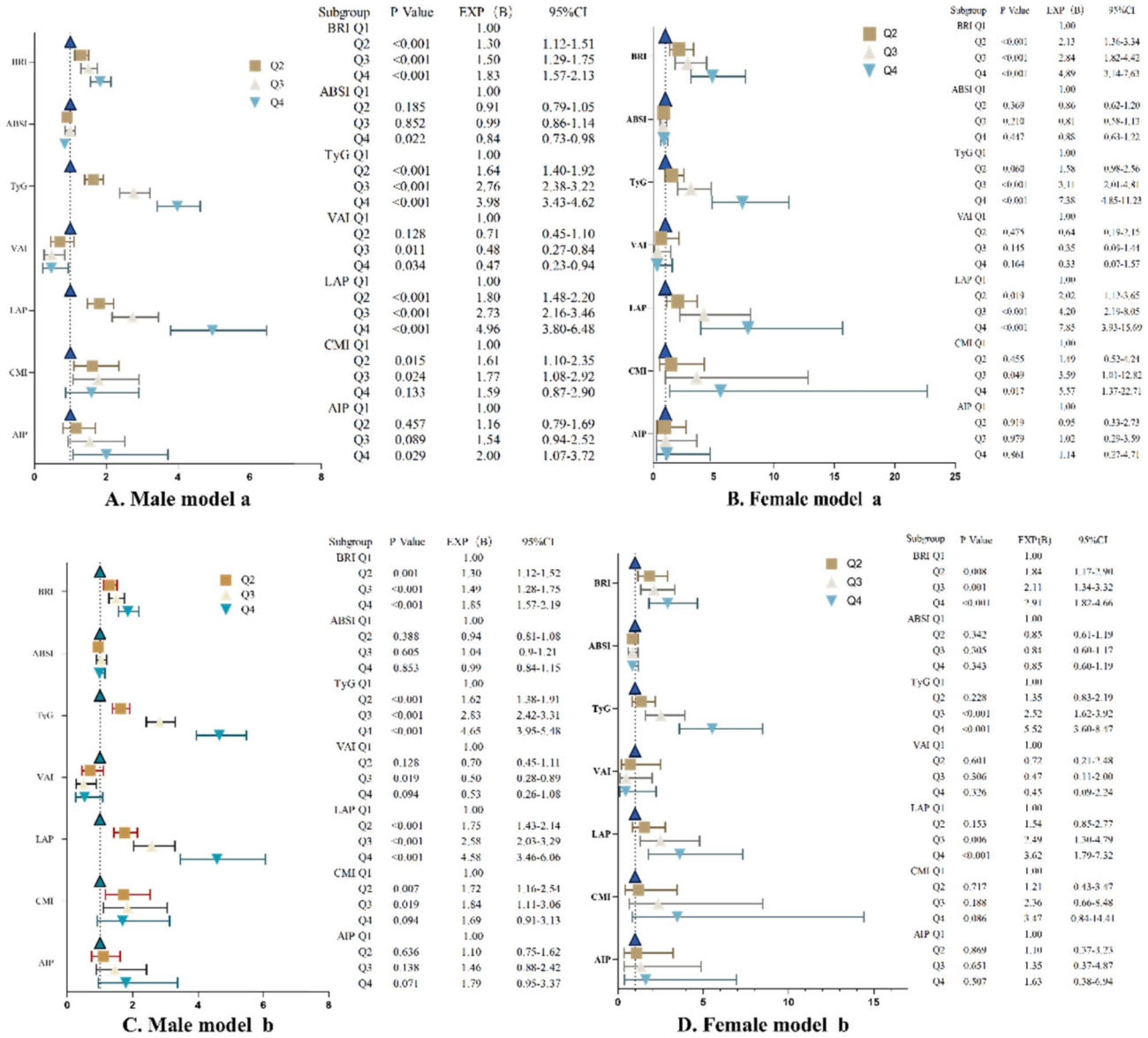

Fig. 2. The novel anthropometric indicators on hyperuricemia. Model a unadjusted; model b adjusted for age, SBP, DBP, FPG, smoking, alcohol consumption, exercise, and diet. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG* index-triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

in renal processing of uric acid[22]. Control of BMI is beneficial in reducing the risk of hyperuricemia, with individuals with increased weight or WC showing a higher propensity for hyperuricemia. BMI, WC, and WHtR are traditional anthropometric measures commonly used for weight management with some limitations. BMI has a weak ability to differentiate between muscle and fat accumulation[5,6], and WC and WHtR are considered specific alternatives for assessing abdominal obesity[23], as well as weak ability to differentiate between visceral and subcutaneous fat[24].

US study finds LAP superior to BMI in identifying adults at cardiovascular risk and may be a better predictor of cardiovascular disease[25]. At the same time, LAP can better predict the risk of metabolic syndrome and diabetes which is superior to BMI and WC in identifying insulin resistance in nondiabetic individuals[26]. Gao et al.[27]compared the ability of BMI and LAP to predict the risk of hypertension in Inner Mongolian males. LAP was found to be more strongly associated with hypertension risk than BMI and may be the anthropometric measure of choice for predicting hypertension risk in men. There are fewer studies on the relationship between LAP and hyperuricemia in humans. The study in Liaoning of China, on the relationship between a novel anthropometric measure and hyperuricemia in a population found LAP was a better predictor of hyperuricemia than BMI (AUC, 0.568)[28]. A recent Korean study also found that LAP was superior to BMI and WC in predicting hyperuricemia in men, but similar to BMI and WC in predicting hyperuricemia in women[29]. The present study demonstrated the predictive value of LAP for hyperuricemia in both male and female participants. In females, LAP predicted

Sex	Variables	AUC (95%CI)	Cut-off	Sensitivity	Specificity	*P*
Female	LAP	0.767 (0.755–0.779)	27.385	0.725	0.687	< 0.001
	TyG	0.746 (0.734–0.75)	8.641	0.666	0.720	< 0.001
	BRI	0.716 (0.704–0.729)	4.531	0.699	0.627	< 0.001
	BMI	0.720 (0.697–0.744)	23.235	0.758	0.585	< 0.001
	WC	0.721 (0.697–0.745)	79.25	0.723	0.600	< 0.001
	WHtR	0.728 (0.704–0.751)	0.491	0.760	0.577	< 0.001
Male	LAP	0.694 (0.682–0.705)	41.755	0.629	0.659	< 0.001
	TyG	0.661 (0.649–0.673)	8.793	0.689	0.560	< 0.001
	BRI	0.599 (0.587–0.612)	4.060	0.742	0.406	< 0.001
	BMI	0.642 (0.630–0.654)	24.810	0.693	0.516	< 0.001
	WC	0.638 (0.626–0.651)	90.150	0.536	0.666	< 0.001
	WHtR	0.626 (0.614–0.638)	0.514	0.650	0.537	< 0.001

Table 6. ROC curve analysis of novel anthropometric indicators on hyperuricemia for prediction of hyperuricemia. *AIP* atherogenic index of plasma, *CMI* cardiometabolic index, *LAP* lipid accumulation product, *VAI* visceral adiposity index, *TyG index* triglyceride glucose index, *ABSI* A body shape index, *BRI* body roundness index.

Sex	Variables	Area difference	Z value	*P*
Female	LAP-TyG	0.022	3.49	< 0.001
	LAP- WHtR	0.039	4.18	< 0.001
	TyG-WHtR	0.018	1.30	0.193
Male	LAP-TyG	0.033	10.73	< 0.001
	LAP-BMI	0.052	8.46	< 0.001
	TyG-BMI	0.019	2.47	0.014

Table 7. Comparison of predictive ability of LAP, TyG index, WHtR and BMI for hyperuricemia. *LAP* lipid accumulation product, *TyG index* triglyceride glucose index, *BMI* body mass index, *WHtR* waist-to-height ratio.

hyperuricemia with an AUC of 0.767, sensitivity of 0.725, and specificity of 0.687. In males, LAP predicted hyperuricemia with an AUC of 0.694, sensitivity of 0.629, and specificity of 0.659, which suggests that LAP is more closely associated with hyperuricemia in females. The mechanisms underlying the predictive ability of LAP for hyperuricemia in this population need further study.

Mazidi et al.[30] found there was a correlation between the TyG index and hyperuricemia in the Caucasian population. A cross-sectional study of 2243 participants in Xinjiang, China, found the TyG index was significantly associated with hyperuricemia and the TyG index was superior to obesity index in identifying hyperuricemia in a Chinese population undergoing medical examinations in Xinjiang, China even after adjusting for multivariable[31]. This study found TyG index was independent influence on hyperuricemia level in population, which was consistent with the results of previous studies. The TyG index is also of great value in identifying bisexual hyperuricemia, especially in women, who may have more complex endocrine factors related to female estrogen. Although our and other previous studies found an association between TyG index and hyperuricemia, it was unclear whether the specific mechanism was related to insulin resistance. Study north of Shanghai, found that compared with BMI, BRI was predictive of hypertension related complications in female individuals, but not in male individuals, and there was a sex difference[32]. This study found that BRI was an independent risk factor for hyperuricemia in Suxi-Chang area and had certain predictive power for hyperuricemia in both men and women. The relationship between BRI and hyperuricemia and the diagnostic ability of BRI need to be further explored.

The results of previous studies on the relationship between new anthropometric indicators and hyperuricemia in the population are also different. The study on the relationship between novel anthropometric measures and hyperuricemia in a population from Liaoning, China, which did not include TyG index, found that BAI, LAP and CMI were strong independent predictors of SUA[28]. A cross-sectional study of 2243 subjects in Xinjiang region of China found the AUC value of TyG index in predicting hyperuricemia was the highest in men (0.586). The AUC value of CMI in women was the highest, and the correlation between TyG index and hyperuricemia was stronger than that between obesity index in men and women, and TyG index was superior to other obesity indexes in identifying hyperuricemia in Xinjiang population[31]. In a recent cross-sectional study in Taiwan, comparing the predictive power of traditional obesity measures and new anthropometric measures for hyperuricemia, LAP had the highest area under the curve (0.691) in men, followed by TyG (0.661) and BMI (0.642). In the female population, the area under the curve (AUC) of LAP was also the highest (0.767), followed by TyG (0.746) and VAI (0.724), suggesting that obesity-related indexes were associated with hyperuricemia, and there were sex

differences, and the association was higher in women than in men[33]. This is a large-scale cross-sectional study on the relationship between new anthropometric indicators and adult SUA level and hyperuricemia in Su-Xi-Chang areas of China. No significant relationship between CMI, ABSI and hyperuricemia level in the relevant population were found, which may be due to differences between regions. The traditional obesity index and the new anthropometric index have certain predictive ability for hyperuricemia in the adult population in Su-Wuxi-Chang area. Among the traditional obesity indicators WHtR had the highest predictive ability for hyperuricemia in women with an AUC of 0.728 and BMI had the highest predictive ability for hyperuricemia in men with an AUC of 0.642. These findings provide a new basis for comprehensive treatment of hyperuricemia in this regional people.

The present study did not find a significant relationship between CMI and ABSI and hyperuricemia in the relevant populations, with possible differences between populations. In this study, we found that traditional obesity indicators and novel anthropometric indices have certain predictive ability for hyperuricemia in adult populations in the Su-Wuxi-Chang area, and the predictive ability of the novel anthropometric indicators LAP and TyG is higher than that of the traditional obesity indicators. LAP has the highest area under the curve, followed by TyG. Among the traditional obesity indicators, WHtR had the highest predictive ability for hyperuricemia in females and BMI had the highest predictive ability for hyperuricemia in males. This result provides a new rationale for the comprehensive treatment of hyperuricemia in this population. Our results underlined the LAP as novel anthropometric indices, were strongly positively associated with hyperuricemia. In clinical practice, LAP which are obtainable and cost-effective could be potential monitoring indicators for hyperuricemia management in overweight/obese individuals. In addition, hyperuricemia can increase mortality, and the study of LAP and cardiovascular death events is also an interesting topic.

Limitations

This study was conducted on a health check-up population and was not based on a population-wide or community-based sample, so the representativeness has some limitations; this study was a cross-sectional study, which could not indicate the causal relationship between the new anthropometric indicators and hyperuricemia, and further prospective intervention studies are needed to clarify the relationship.

Data availability

The raw data supporting the conclusions of this paper will be made available by the authors without reservation and can be obtained from the corresponding author.

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Author contributions

Li Hongwei, Shen Zhenhai, Jiang Wei and Jia Bing contributed equally to this work. Li Hongwei, Shen Zhenhai, Jiang Wei and Jia Bing analyzed the results and wrote the manuscript. Li Shaolei and Zhang Ping made the statistical comparison. Wang Liuyu and Yuan Peng collected the data. Lu Yun conceived and designed the study. All authors have read and approved the final manuscript. All authors have read and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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