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Association between serum uric acid and measures of adiposity in Chinese adults: a cross-sectional study

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ABSTRACT

Objective The purposes of the study were to investigate the detailed association of serum uric acid (SUA) with visceral fat area (VFA) and body fat percentage (BFP) as calculated by bioelectrical impedance analysis (BIA) and build non-invasive diagnosis models of hyperuricaemia by combining obesity-related indicators, age and sex.

Method A total of 19 343 adults were included. Multivariable regression analysis models were employed to analyse the association of SUA with VFA and BFP. Receiver operating characteristic curves were generated to diagnose hyperuricaemia in adults.

Results After fully adjusting for covariates, SUA was positively associated with VFA, BFP and body mass index (BMI) with βs of 0.447, 2.522 and 4.630 (95% CI= (0.412 to 0.482), (2.321 to 2.723) and (4.266 to 4.994)). After stratification by gender, this association persists (p<0.001). Fitted smoothing curves identified non-linear relationships between SUA and both VFA and BMI after full adjustment in males (inflection points: 93.9 cm^2 and 30.9 kg/m^2). A non-linear relationship also exists between SUA and BFP in females (inflection point: 34.5%). A combined model incorporating BFP, BMI, age and sex exhibited the best ability to diagnose hyperuricaemia (AUC (area under the curve) =0.805, specificity=0.602, sensitivity=0.878). For normal-weight and lean populations, individuals with hyperuricaemia tended to have higher levels of VFA and BFP in females and males, respectively (p<0.001). The combination of VFA, BFP, BMI, age and sex exhibited the best ability to diagnose hyperuricaemia in normal-weight and lean populations (AUC=0.803, specificity=0.671, sensitivity=0.836).

Conclusion VFA and BFP are independent factors associated with SUA. In males, SUA shows a non-linear relationship with VFA and BMI. In females, SUA and BFP exhibit a non-linear relationship. In normal-weight and lean individuals, the accumulation of VFA and BFP may be involved in hyperuricaemia. VFA and BFP were helpful in diagnosing hyperuricaemia in adults, especially for normal-weight and lean populations.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study has a large sample size, making it one of the largest studies investigating the association between serum uric acid (SUA) and both visceral fat area and body fat percentage. This provides more reliable and precise estimates of the associations.
⇒ The bioelectrical impedance analysis method used in the study is a simple and low-cost method of measuring body adiposity, which increases the convenience and accessibility of the research results for wider use.
⇒ The study did not account for lifestyle factors such as physical activity, diet and alcohol consumption, which could affect uric acid levels and contribute to the associations observed in the study.
⇒ The study did not collect data on antihypertensive, antidiabetic and lipid-lowering therapies, which could affect the association between SUA and body composition variables. This limits the generalisability of the study results to individuals who are not receiving these types of treatments.

INTRODUCTION

Hyperuricaemia is a disorder of purine metabolism that affects approximately 120 million individuals in China, making it the second most prevalent metabolic disease after diabetes mellitus (DM).[1] Hyperuricaemia is an independent risk factor for DM, high blood pressure(HBP) and cardiovascular diseases,[2 3] and gout due to hyperuricaemia is an independent predictor of premature death.[4] The association between serum uric acid (SUA) and obesity has been well documented.[5] Obese individuals are more prone to developing hyperuricaemia,[6] and in those with increased visceral fat, SUA production is significantly increased while the renal excretion rate is decreased.[7] Weight loss can lead to a significant decrease in SUA levels.[8] However, lifestyle factors such as diet, physical activity and alcohol consumption may also play a role in the development of hyperuricaemia.

Currently, body mass index (BMI) is the main index used to evaluate the association between SUA and obesity, while there is a lack of large studies investigating the relationship between SUA and visceral or body fat. VFA is an important indicator of body adiposity, closely linked to metabolism, and holds significant clinical value in evaluating hidden obesity. Moreover, body fat distribution is strongly associated with insulin

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resistance and health risks related to obesity.[9] Various imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI) and dual energy X-ray absorptiometry (DXA) are commonly used to assess body composition, including visceral fat and body fat distribution. However, their widespread use is limited by their specialised facilities, high costs and complex operational requirements. In recent years, bioelectrical impedance analysis (BIA) has become increasingly popular due to its simplicity and affordability. In this study, we utilised BIA to calculate VFA and BFP and to investigate the relationship between body composition and SUA. Moreover, we aimed to establish a non-invasive diagnostic model for hyperuricaemia by integrating age, sex and obesity-related indicators. Online supplemental table 1 provides the differences in methods for measuring human fat distribution using nuclear magnetic resonance, CT, DXA and BIA.

In addition to its association with obesity, hyperuricaemia has also been found to be related to multiple metabolic diseases in the non-obese population. Specifically, in non-obese individuals with normal glucose levels, hyperuricaemia has been shown to be correlated with increased insulin release.[10] SUA has also been identified as a significant risk factor for non-alcoholic fatty liver disease in non-obese and lean individuals.[11] The potential impact of body composition assessment on the prevalence of hyperuricaemia among non-obese patients remains largely unexplored. This study aims to investigate the relationship between body fat percentage (BFP), visceral fat area (VFA) and SUA levels in non-obese individuals. Additionally, we aimed to develop a model for identifying hyperuricaemia in normal-weight and lean populations by utilising a combination of BIA indexes.

SUBJECTS AND METHODS

Subjects

In this study, we retrospectively analysed physical examination data of adults aged 18 years or older who underwent human body composition analysis by BIA at the Health Management Center of Nanjing Drum Tower Hospital from January 2018 to March 2022. The inclusion criteria were: (1) complete clinical data, including age, gender, systolic blood pressure (SBP), diastolic blood pressure (DBP), medical history and biochemical indexes (fasting blood glucose (FBG), haemoglobin (HbA1c), total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c) and other indexes); (2) individuals who were not taking drugs which affects SUA such as inhibiting purine synthesis (eg, allopurinol and febuxostat) or promoting uric acid excretion (eg, benzbromarone, diuretics, etc); (3) individuals without severe comorbidities such as chronic coronary syndrome, atrial fibrillation, cancers and renal failure. The exclusion criteria were: (1) incomplete clinical data records; and (2) incomplete medical history records.

Methods

The study collected general information on participants, including their physical examination number, age and gender, as well as medical history information, including DM, HBP and other relevant data. Blood pressure was measured by having subjects rest in a quiet environment for 10–20 min before measurements were collected using an electronic sphygmomanometer.

Height, weight and body composition were measured in the morning with subjects instructed to fast, void their urinary and faecal contents, remove metal ornaments and wear light clothes prior to measurement. Measurements were collected using electronic weight scales and height measurement tools.

The study utilised an H-key350 human body composition analyzer (Beijing Sihaihuachen Technology) to calculate VFA and BFP. During measurement, the subject stood barefoot on the instrument, ensuring that both feet made full contact with the foot-shaped electrodes on the instrument panel. The subject held the side handles with both hands, ensuring that all five fingers made full contact with the test electrode. The subject was instructed to maintain a trunk angle of about 15º and straighten their arms to both sides while maintaining a quiet posture for 2–3 min.

To detect serum biochemical indexes, 3 mL of peripheral venous blood was collected from fasting subjects, and an automatic biochemical analyzer was used to measure FBG, HbA1c, TC, HDL-c, LDL-c, TG, SUA and other relevant values.

Ethics

The study was conducted under the project titled 'Construction of a Full Life Cycle Intelligent Monitoring Management Service System Model based on Diagnosis Related Groups (DRGs),' which received approval from the Ethics Committee of Nanjing Drum Tower Hospital (2022-046-01).

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Statistical analysis

Non-normally distributed continuous variables were expressed as median and quartiles. Categorical variables were expressed as percentages. Normal-weight and lean individuals were defined as those with a BMI <25 kg/m^2.[12] The diagnosis of hypertension was based on medical history complaints and the finding of SBP ≥140 mm Hg and/or DBP ≥90 mm Hg during physical examination. The diagnosis of DM was based on medical history complaints and/or the finding of FBG ≥7 mmol/L and/or HbA1c ≥6.5% during physical examination. Hyperuricaemia was defined as a SUA level greater than 420 µmol/L. Hyperuricaemia was also defined with a lower cut-off value of 303 µmol/L for females and 333 µmol/L for males according to the URRAH project.[13]

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Baseline characteristics between males and females were compared using the Kruskal-Wallis rank sum test for continuous variables and the χ^2 test for categorical variables. Multivariable regression analysis models were used to analyse the association of SUA with VFA, BFP and BMI, adjusting for covariates including age, sex, HBP, SBP, DBP, DM, FBG, HBA1c, ALT, AST, TC, HDL-c, LDL-c, TG and serum creatinine (SCr). Smooth fitting curves and threshold analysis with additive models were used to identify possible inflection points in the effect of VFA on SUA. Interaction and stratified analysis were conducted according to sex. The areas under curves (AUCs) of receiver operating characteristic (ROC) were used to measure the diagnosability of hyperuricaemia using BMI, BFP, VFA and the combined models. All analyses were performed using R software and EmpowerStats (http://www.empowerstats.com), with p<0.05 taken to indicate a statistically significant difference.

RESULTS

Description of baseline information of the study population

From January 2018 to March 2022, data from 19343 physical examinees (8574 females and 10 769 males) who met the inclusion and exclusion criteria were included in the study. Significant differences were observed between females and males in terms of age, BMI, HBP, DM, TC, LDL-C, TG, FBG, HbA1c, AST, ALT, SCr, VFA, BFP, BMI, and SUA (all p<0.001). Please refer to table 1 for detailed information.

Association between SUA and VFA, BFP

Multivariable linear regression models were used to examine the association between SUA and VFA, BFP and BMI. The results showed that SUA was positively associated with VFA, BFP and BMI, with β values of 0.447, 2.522 and 4.630 (95% CI=0.412 to 0.482, 2.321 to 2.723 and 4.266 to 4.994), respectively. In females, positive associations were observed, with β values of 0.396, 2.356 and 4.020 (95% CI=0.354 to 0.437, 2.113 to 2.600 and 3.560 to 4.479), respectively. Similarly, in males, positive relationships were found, with β values of 0.479, 2.665 and 4.713 (95% CI=0.424 to 0.534, 2.358 to 2.971 and 4.174 to 5.253), respectively. Refer to table 2 for further details.

Non-linear relationship between uric acid and VFA

The relationships between SUA and VFA, BFP and BMI were analysed using fitted smooth curves and threshold effect analysis. The fitted smooth curves demonstrated that, after adjusting for covariates, non-linear relationships with inflection points were found between SUA and both VFA and BMI in males. In females, a non-linear

Table 1 Baseline characteristic of 19343 physical examinees

Items	Total (n=19343)	Female (n=8574)	Male(n=10 769)	P value
Age (years)	51.00 (41.00–56.00)	52.00 (43.00–57.00)	50.00 (40.00–56.00)	<0.001
Sex (n (%))=male	10 769 (55.67%)	0 (0.00%)	10 769 (100.00%)	<0.001
BMI (kg/m^2)	24.60 (22.40–26.80)	23.40 (21.40–25.70)	25.40 (23.50–27.40)	<0.001
SBP (mm Hg)	128.00 (117.00–141.00)	125.00 (114.00–140.00)	130.00 (119.00–142.00)	<0.001
DBP (mm Hg)	80.00 (72.00–88.00)	77.00 (69.00–85.00)	82.00 (75.00–90.00)	<0.001
BFP (%)	27.90 (23.50–32.70)	32.20 (27.90–36.00)	25.10 (21.60–28.70)	<0.001
VFA (cm^2)	83.60 (65.50–106.90)	88.10 (66.30–116.50)	81.20 (64.80–100.00)	<0.001
SUA (μmol/L)	345.00 (284.00–413.00)	288.00 (248.00–334.00)	394.00 (340.00–451.00)	<0.001
TC (mmol/L)	4.94 (4.35–5.58)	5.01 (4.40–5.65)	4.89 (4.31–5.53)	<0.001
HDL-c (mmol/L)	1.31 (1.09–1.59)	1.49 (1.25–1.77)	1.19 (1.01–1.41)	0.574
LDL-c (mmol/L)	2.89 (2.40–3.43)	2.89 (2.39–3.44)	2.90 (2.41–3.43)	<0.001
TG (mmol/L)	1.23 (0.84–1.82)	1.04 (0.74–1.50)	1.40 (0.97–2.08)	<0.001
FBG (mmol/L)	4.92 (4.60–5.37)	4.83 (4.53–5.22)	5.01 (4.66–5.51)	<0.001
HbA1C (%)	5.50 (5.30–5.80)	5.50 (5.30–5.80)	5.50 (5.30–5.90)	<0.001
ALT (IU/L)	20.00 (14.50–29.40)	16.25 (12.50–22.30)	23.80 (17.40–34.80)	<0.001
AST (IU/L)	20.10 (17.10–24.40)	19.20 (16.40–22.90)	20.90 (17.70–25.50)	<0.001
SCr (μmol/L)	62.00 (52.00–72.00)	52.00 (47.00–57.00)	71.00 (64.00–78.00)	<0.001
HBP (n (%))	7468 (38.61%)	2775 (32.37%)	4693 (43.58%)	<0.001
DM (n (%))	1943 (10.04%)	602 (7.02%)	1341 (12.45%)	<0.001

Continuous variables, such as age, VFA, BFP and UA, were expressed as median and quartile (Q1–Q3). Categorical variables, such as gender and DM, were expressed as percentages. P value represents the statistical difference between male and female groups; p value of a continuous variable, obtained by Kruskal-Wallis rank sum test. The categorical variable adopts the χ^2 test.
ALT, alanine aminotransferase; AST, aspartate transaminase; BFP, body fat percentage; DM, diabetes mellitus; FBG, fasting blood glucose; HbA1c, glycosylated haemoglobin; HBP, high blood pressure; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; SUA, serum uric acid; TC, total cholesterol; TG, triglyceride; VFA, visceral fat area.

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Table 2 Association between uric acid and VFA, BFP and BMI

Exposure	β	95% CI	P value	P interaction
VFA (cm^2)	0.447	0.412 to 0.482	<0.001	0.008
Female	0.396	0.354 to 0.437	<0.001	
Male	0.479	0.424 to 0.534	<0.001	
BFP (%)	2.522	2.321 to 2.723	<0.001	0.070
Female	2.356	2.113 to 2.600	<0.001	
Male	2.665	2.358 to 2.971	<0.001	
BMI (kg/m^2)	4.630	4.266 to 4.994	<0.001	0.181
Female	4.020	3.560 to 4.479	<0.001	
Male	4.713	4.174 to 5.253	<0.001	

Age, sex, HBP, DM, ALT, AST, TC, HDL-c, LDL-c, TG, and SCr were adjusted. Gender was not adjusted when stratified by gender.
ALT, alanine aminotransferase; AST, aspartate transaminase; BFP, body fat percentage; DM, diabetes mellitus; HBP, high blood pressure; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; SUA, serum uric acid; TC, total cholesterol; TG, triglyceride; VFA, visceral fat area.

relationship was observed between BFP and SUA (see figure 1 for details).

Generalised additive models were used for threshold effect analysis to investigate the non-linear association between VFA, BFP and SUA. A non-linear relationship was found between SUA and VFA in males, with an inflection point of 93.9 cm^2. Specifically, for VFA values below the inflection point, every 1 cm^2 increase was associated with a 0.676 µmol/L increase in SUA, while for values above the inflection point, every 1 cm^2 increase was associated with a 0.311 µmol/L increase in SUA. In females, a non-linear relationship was observed between SUA and BFP, with an inflection point of 34.5%. For BFP values below the inflection point, every 1% increase was associated with a 1.909 µmol/L increase in SUA, while for values above the inflection point, every 1% increase was associated with a 3.350 µmol/L increase in SUA. In males, a non-linear relationship was found between SUA and BMI, with an inflection point of 30.9 kg/m^2. For BMI values below the inflection point, every 1 kg/m^2 increase was associated with a 5.171 µmol/L increase in SUA, while for values above the inflection point, every 1 kg/m^2 increase was associated with a 1.350 µmol/L increase in SUA. Details can be found in table 3.

Body composition in the diagnosis of hyperuricaemia

ROC curve analysis was conducted to evaluate the diagnostic performance of VFA, BFP and BMI, both individually and in combination, for hyperuricaemia. The corresponding AUC values, ranked in ascending order, were as follows: BFP (AUC=0. 5515, 95% CI: 0.54244 to 0.5607), VFA (AUC=0.5782, 95% CI: 0.5689 to 0.5874), BMI (AUC=0.6883, 95% CI: 0.6797 to 0.6997), Model 2 (AUC=0.7495, 95% CI: 0.7419 to 0.7570), Model 4 (AUC=0.7951, 95% CI: 0.7883 to 0.8018), Model 1 (AUC=0.8052, 95% CI: 0.7984 to 0.8120) and Model 3 (AUC=0.8053, 95% CI: 0.7985 to 0.8121). Further details are presented in online supplemental table 2 and figure 2A.

Body adiposity characteristics in normal-weight and lean populations with or without hyperuricaemia

In normal-weight and lean populations, females with hyperuricaemia exhibited higher VFA and BFP values than those without hyperuricaemia (88.15 (72.25–105.93) vs 73.20 (59.80–92.30) cm^2, 32.35 (29.28–34.90) vs 29.70 (26.10–33.00)% (p<0.001)). In normal-weight and lean populations, males with hyperuricaemia exhibited higher VFA and BFP values than those without hyperuricaemia (67.40 (55.70–78.20) vs 62.40 (50.70–74.05) cm^2, 22.80 (19.70–25.50) vs 21.40 (18.20–24.30)% (p<0.001)). See details in online supplemental table 3. The combination of BMI, BFP, VFA, age and sex had the highest diagnostic capability for hyperuricaemia (AUC=0.8031 (95%CI=0.7923 to 0.8140)), with a specificity of 0.6712 and sensitivity of 0.8355. See details in online supplemental table 4 and figure 2B.

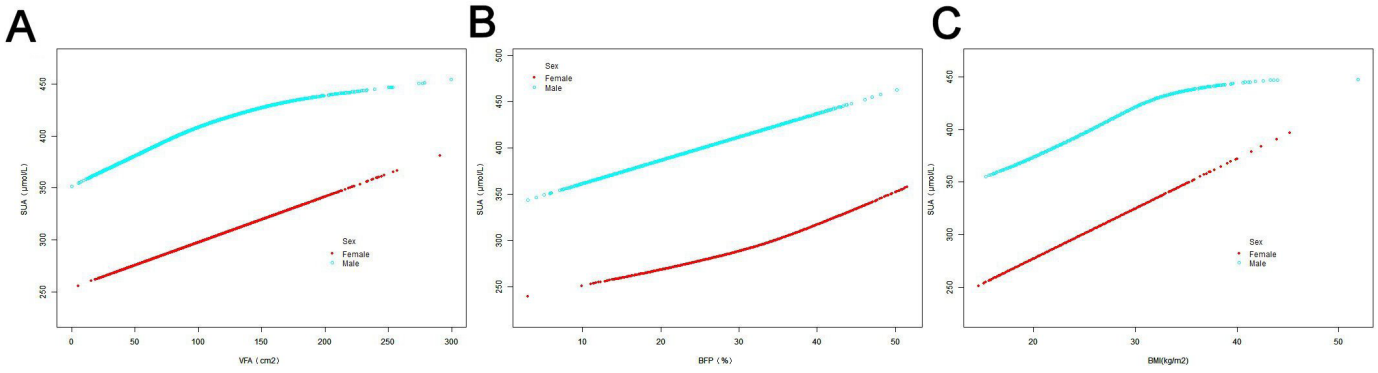

Figure 1 Smooth fit curve for body composition indexes and SUA. Notes: age, sex, HBP, SBP, DBP, DM, FBG, HbA1c, ALT, AST, TC, HDL-c, LDL-c, TG and SCr were adjusted. ALT, alanine aminotransferase; AST, aspartate transaminase; BFP, body fat percentage; BMI, body mass index; HbA1c, haemoglobin; HBP, high blood pressure; DBP, diastolic blood pressure; DM, diabetes mellitus; FBG, fasting blood glucose; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SUA, serum uric acid; TC, total cholesterol; TG, triglyceride; VFA, visceral fat area.

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Table 3 Threshold effect analysis for SUA and VFA using a two-piecewise linear regression model

Exposure	VFA in males			BFP in females			BMI in males		
	β	95% CI	P	β	95% CI	P	β	95% CI	P
Model 1									
Standard linear model	0.479	0.424 to 0.534	<0.001	2.356	2.113 to 2.599	<0.001	4.714	4.174 to 5.253	<0.001
Model 2									
Two-piecewise linear model									
Inflection point	93.9			34.5			30.9		
<Inflection point	0.676	0.577 to 0.776	<0.001	1.909	1.567 to 2.252	<0.001	5.171	4.560 to 5.782	<0.001
>Inflection point	0.311	0.222 to 0.401	<0.001	3.350	2.760 to 3.939	<0.001	1.350	−0.836 to 3.536	0.226
Likelihood ratio	<0.001			<0.001			0.002		

Age, HBP, DM, ALT, AST, TC, HDL-c, LDL-c, TG and SCr were adjusted.
ALT, alanine aminotransferase; AST, aspartate transaminase; BFP, body fat percentage; BMI, body mass index; DM, diabetes mellitus; HBP, high blood pressure; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; VFA, visceral fat area.

Body adiposity in the diagnosis of hyperuricaemia with lower cut-off value

The ROC curve analysis was conducted to evaluate the diagnostic performance of VFA, BFP and BMI, either alone or in combination, for diagnosing hyperuricaemia with a lower cut-off value. The combination of age, sex, BMI, BFP and VFA had a diagnostic capability of AUC=0.7588 (95% CI=0.7519 to 0.7656) for hyperuricaemia with a lower cut-off value (refer to online supplemental table 5 and figure 1 for more details). In both sexes, hyperuricaemia was found to be associated with higher levels of VFA and BFP in normal-weight and lean populations (refer to online supplemental table 6 for more details). For hyperuricaemia in normal-weight and lean populations with a

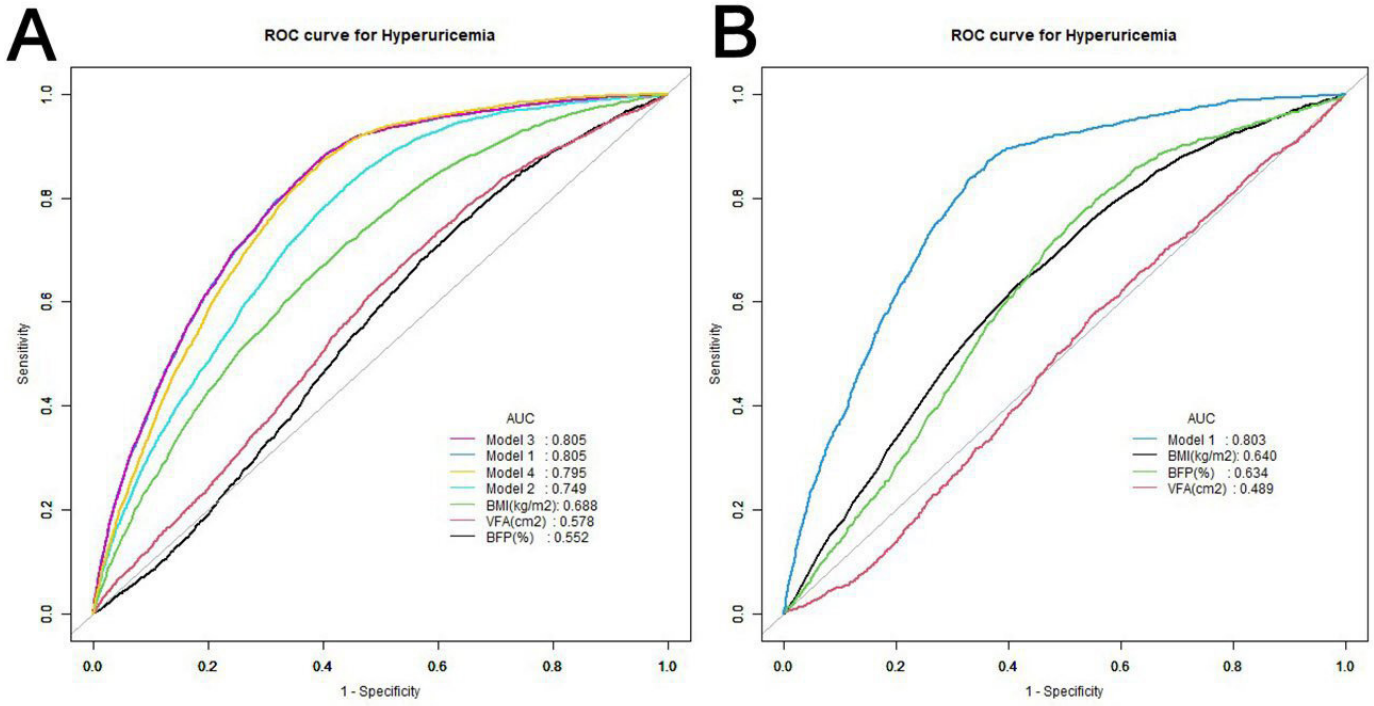

Figure 2 ROC curves of hyperuricaemia for BMI, VFA, BFP and the combined model. (A) For the whole population: Model 1 (age+gender+BMI+BFP+VFA): logit(hyperuricaemia)=−6.00014+0.05207*BFP−0.00397*VFA+0.12259*BMI+2.66719*SEX−0.02771*AGE; Model 2 (BFP+BMI+VFA): logit(hyperuricaemia)=−4.68798−0.15314*BFP+0.01298*VFA+0.25787*BMI. Model 3 (BFP+BMI+sex+age): logit(hyperuricaemia)= −5.56092 +0.03729*BFP+0.10761*BMI+2.63569*SEX−0.02747*AGE; Model 4 (BMI+BFP+Sex): logit(hyperuricaemia)= −6.91626+0.02620*BFP+0.12173*BMI+2.59018*SEX. (B) For normal and lean populations: Model 1 (age+gender+BMI+BFP+VFA): logit(hyperuricaemia)= −6.56135 +0.04708*BFP+0.00246*VFA+0.11388*BMI+2.88429*SEX−0.02269*AGE. AUC, area under the curve; BFP, body fat percentage; BMI, body mass index; ROC, receiver operating characteristic; VFA, visceral fat area.

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lower cut-off value, the combination of age, sex, BMI, BFP and VFA had a diagnostic capability of AUC=0.7268 (95% CI=0.7172, 0.7363) (refer to online supplemental table 7 and figure 2 for more details).

DISCUSSION

This study has found that VFA and BFP are both independently associated with SUA levels. Additionally, in males, SUA demonstrated a non-linear relationship with both VFA and BMI, while in females, SUA exhibited a non-linear relationship with BFP. The study suggests that the accumulation of VFA and BFP may contribute to elevated SUA levels in normal-weight and lean individuals. Furthermore, the study indicates that body adiposity assessment, as determined by BIA, can be a useful diagnostic tool for identifying hyperuricaemia in adults, including those who are normal-weight and lean.

In recent years, numerous epidemiological studies have been conducted to investigate the relationship between fat distribution and SUA. However, due to limited sample sizes and ethnic differences, the findings of these studies cannot be accurately extrapolated to Chinese populations.[14–16] Furthermore, the conclusions of these studies are inconsistent.[17] To our knowledge, this study represents the largest sample size investigation of the relationships between SUA, VFA and BFP in Chinese adults. Common methods for evaluating body composition include CT, MRI, DXA and BIA.[18] However, it should be noted that BIA does not directly measure fat, but rather calculates it indirectly. Our study utilised BIA due to its advantages of simple operation and low cost.[19 20] BIA has been widely used in weight loss clinics, gyms and other settings over the past few decades. This research also represents the largest known study to calculate human body adiposity using BIA.[21]

We observed a positive correlation between VFA and SUA, with every 1 cm^2 increase in VFA corresponding to a SUA increase of 0.45 µmol/L (0.48 µmol/L for males and 0.40 µmol/L for females). Similar findings have been reported by previous studies. For instance, Rospleszcz *et al* found a positive correlation between visceral adipose tissue, measured by MRI and SUA after adjusting for age and BMI,[14] and Lee *et al* reported a positive correlation between VFA, as evaluated by DXA, and SUA among obese individuals.[17] Additionally, it was found that the lipid accumulation product presents the highest OR for the association with hyperuricaemia.[22] Regarding BFP, we found that for every 1% increase, there was a corresponding SUA increase of 2.52 µmol/L (2.36 µmol/L for males and 2.67 µmol/L for females). In contrast, one study exploring the relationship between total body fat measured by DXA and SUA found that SUA increased by 0.99 for every 1% increase in total body fat.[23] This discrepancy in findings may be due to differences in race and detection methods.

Some existing evidence can explain the correlation with adipose tissue. Obesity is an independent risk factor for hyperuricaemia. SUA is the product of purine metabolism in the body. Its levels are primarily determined by levels of uric acid production and SUA excretion by the kidneys.[24] In obese individuals, body fat and visceral fat accumulation can increase the level of free fatty acids, which participate in de novo purine synthesis and thus increase SUA production.[25 26] On the other hand, hyperinsulinaemia and insulin resistance in obese patients can promote the reabsorption of sodium by the renal tubules, reducing SUA clearance and improving levels of SUA.[27 28] Body fat and visceral fat accumulation are important features of obese patients, and visceral fat is also an important factor in the occurrence of insulin resistance.[29] VFA is an evaluation index of visceral fat, so it is closely related to SUA levels.

Our study suggests that SUA levels may be more susceptible to fat distribution in males. Previous research has shown a similar phenomenon.[23] These findings may be attributed to differences in human sex hormones between different genders. Studies have found that oestrogen replacement therapy can reduce SUA levels.[30] It has also been found that progesterone combined with oestrogen supplementation can reduce levels of SUA in postmenopausal women, while the effect of oestrogen alone on SUA is not obvious.[31] Animal studies have found that oestrogen can inhibit the SUA-generating enzyme xanthine oxidase in the rat liver, reducing SUA levels.[32] Therefore, SUA levels will also increase in postmenopausal women. Some studies have shown that testosterone levels in adult males are negatively correlated with SUA levels[33]; however, the different contributions of hormones to SUA may be the reason for gender-related differences. Interestingly, our study also identified a threshold effect in the relationship between SUA and VFA, BFP and BMI. In males, the inflection points of VFA and BMI were 93.9 cm^2 and 30.9 kg/m^2. In females, the inflection point of BFP was 34.5%. There is no clear mechanistic explanation for these differences in prethreshold and post-threshold behaviour.

Hyperuricaemia is closely related to glucose and lipid metabolic disorders. VFA and BFP are effective indexes for the evaluation of implicit obesity.[34] Controlling BFP and VFA can help to reduce SUA levels and reduce the risk of secondary metabolic diseases. However, the partial contributions of VFA and BFP to hyperuricaemia are also important to consider. For every 1 cm^2 increase in VFA, SUA can increase by 0.45 µmol/L, partially affecting SUA level. Our results suggest that, in order to control SUA levels by controlling visceral fat, a large reduction is required to substantially improve SUA. These findings should also prompt researchers to further explore influencing factors related to SUA.

Hyperuricaemia can also occur in the non-obese population.[10] Our study suggests that hyperuricaemia in normal-weight and lean individuals may be related to fat distribution (VFA and BFP). Therefore, we believe that even individuals with normal BMIs can benefit from controlling fat distribution to reduce SUA and hyperuricaemia risk. In diagnosing hyperuricaemia, a

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model based on the combination of BFP, BMI, age and sex exhibited the best performance across the whole population (AUC=0.805), with relatively high sensitivity (87.8%). Therefore, BIA is recommended as a noninvasive method to screen for hyperuricaemia when it is not feasible to collect invasive blood biochemistry data and conduct invasive blood tests. Model 1 (with VFA) and Model 3 (without VFA) exhibited similar AUC values, possibly because BFP represents adipose tissue, including visceral fat. In normal-weight and lean individuals, hyperuricaemia is easily ignored. Our model for the diagnosis of hyperuricaemia exhibited an AUC of 0.803 and high sensitivity (83.6%). The model's specificity is relatively low, which means that it may incorrectly classify participants without hyperuricaemia. Although the model combines various weight-related indicators, it may not effectively capture all factors that affect uric acid levels. Therefore, future models may need to consider additional uric acid-related indicators beyond those related to body fat, highlighting the complexity of uric acid regulation. Although if, therefore, we recommend applying this model as a non-invasive method of screening for hyperuricaemia. The URRAH project tend to defined hyperuricaemia with the lower cut-off value to decrease the cardiovascular disease risk.[13] However, our study found the adiposity measures combination do not display higher diagnosis ability of hyperuricaemia lower cut-off value than of the higher value.

There are advantages and limitations to our research. This study is the largest study by sample size on the association between SUA and both VFA and BFP performed on the Chinese mainland. The BIA method is simple and low-cost, and the research results are convenient to be widely used. This study also has some disadvantages. For example, the medical histories of the study population were provided by the subjects based on their complaints, rather than with the active consultation of researchers, potentially leading to information omission. In our study, only four subjects had been diagnosed with hyperuricaemia, and their medication histories are unknown. Data on antihypertensive, antidiabetic and lipid-lowering therapies were not available in our study, which may have influenced our results. This study did not address factors related to lifestyle, such as physical activity, eating habits and alcohol consumption,[27] which may affect uric acid levels.[35] Due to data limitations, this study only evaluated the effects of VFA and BFP on SUA and did not evaluate the effect of subcutaneous fat.

CONCLUSION

VFA and BFP are independent association factors of SUA. In males, SUA exhibits a non-linear relationship with VFA and BMI, while SUA and BFP exhibit a non-linear relationship in females. In normal-weight and lean individuals, the accumulation of VFA and BFP might be involved in increasing SUA levels. BIA-based body adiposity assessment provides a non-invasive and cost-effective approach to diagnosing hyperuricaemia in adults, including those who are normal-weight or lean.

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