Preventive Medicine Reports 45 (2024) 102843

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

The association between visceral adipose accumulation and hyperuricemia risk among Chinese elder individuals: A nationwide prospective cohort study

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ARTICLE INFO

Keywords:
Visceral adipose accumulation
Chinese visceral adipose accumulation
Hyperuricemia
Cohort study
Visceral adiposity index
Lipid accumulation product

ABSTRACT

Background: Lipid accumulation product (LAP), visceral adiposity index (VAI) and Chinese visceral adiposity index (CVAI) are proposed indices of visceral adipose accumulation. This study aimed to explore their relationship and temporal changes with hyperuricemia (HUA) development in a Chinese population.

Methods: A total of 4268 participants aged ≥45 years from the baseline survey of the China Health and Retirement Longitudinal Study were followed up for 4 years (from 2011 to 2015). The relationships among VAI, LAP, CVAI and HUA were analyzed using logistic regression. The predictive abilities of the VAI, LAP and CVAI for HUA were compared using receiver operating characteristic curves. Nonlinear relationships between the indices and HUA were analyzed using restricted cubic spline regression.

Results: During the four-year follow-up, 415 (9.72 %) patients experienced incident HUA . Elevated baseline VAI (odds ratio (OR): 1.19 (95 % confidence interval (95 %CI: 1.10, 1.29)), LAP (OR: 1.21 (95 % CI: 1.09, 1.34)) and CVAI (OR: 1.19 (95 % CI: 1.02, 1.40)) were significantly correlated with increased HUA risk (all $P < 0.05$). Compared to individuals with consistently low VAI,CVAIor LAP levels, those with elevated or consistently high levels of these indicators are more likely to have HUA. The area under curve (AUC) was slightly greater and more significant for the CVAI (AUC=0.641) than for the VAI (AUC=0.604) and LAP (AUC=0.628) ($P < 0.05$).

Conclusion: VAI, LAP and CVAI can predict HUA, with CVAI more efficient than VAI and LAP. Early management can lessen the burden of HUA in Chinese people aged 45 years or older with elevated CVAI levels.

1. Introduction

Hyperuricemia (HUA) is a disorder of uric acid secretion in the body, leading to gout (Li et al., 2019). It has become a significant public health concern, with a notable increase in incidence across multiple countries (Kumar et al., 2018, Chen-Xu et al., 2019). Many studies have demonstrated a strong association between HUA and metabolic disorders, especially chronic kidney disease, diabetes, and cardiovascular diseases (Qian et al., 2021, Liu et al., 2020, Liu et al., 2018, Bartáková et al., 2016, Khichar et al., 2017). Recent trends show increased HUA prevalence among younger age groups. Left uncontrolled, HUA can progress to a lifelong condition, significantly impacting the patient's quality of life and imposing a substantial disease burden on society (Suttikomin et al., 2018, Lee, 2019). Therefore, investigating the factors associated with HUA and implementing preventive measures is necessary to mitigate the overall disease burden.

Recent studies indicate that body fat negatively affects HUA; however, the relationship between body fat distribution and HUA remains unclear (Chen et al., 2016, Godin et al., 2015). Previous studies reveal that waist circumference (WC) and body mass index (BMI) cannot distinguish between central and peripheral fat, subcutaneous fat, and visceral fat (Wang et al., 2018, Zhang et al., 2013, Jiang et al., 2017). In addition, HUA prevalence increases in individuals with high visceral adipose tissue content after adjusting for BMI and waist circumference (Huang et al., 2019, Dong et al., 2017). While Magnetic Resonance Imaging and computed tomography are commonly used to quantify visceral fat content, their feasibility for large-scale epidemiological studies is limited. Therefore, indicators such as lipid accumulation

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https://doi.org/10.1016/j.pmedr.2024.102843
Received 23 February 2024; Received in revised form 1 August 2024; Accepted 1 August 2024
Available online 5 August 2024

product (LAP), visceral adiposity index (VAI) and Chinese visceral adiposity index (CVAI), calculated based on age, BMI, waist circumference, high-density lipoprotein cholesterol (HDL-c), and triglycerides (TG), have been proposed to measure visceral adipose distribution (Amato and Giordano, 2014, Cicero et al., 2018, Xia et al., 2016). Studies have demonstrated that lipid accumulation products can better predict the relationship between obesity and cardiovascular disease (CVD) and diabetes than traditional obesity measures such as BMI (Fan et al., 2021, Yu et al., 2021, Yu et al., 2022).

Previous studies identified a positive correlation between HUA and visceral adipose accumulation (Huang et al., 2019, Zhou et al., 2022). However, there remains uncertainty about which visceral adipose accumulation index best predicts HUA. Emerging evidence indicates that HUA associated with visceral adipose tissue depends on lipid degree and distribution (Wang et al., 2018, Seong et al., 2021). Nevertheless, evidence on how changes in visceral lipid accumulation affect HUA risk is scarce and poorly understood. Furthermore, no studies have yet explored the relationship between alterations in LAP, VAI, or CVAI and the risk of hyperuricemia (HUA).

This study examined the associations and predictive abilities of LAP, VAI and CVAI with HUA risk in a Chinese population aged ≥45 years. Based on a national prospective cohort, it aimed to provide valuable insights into the early detection and prevention of HUA.

2. Methods

2.1. Study population

This study was based on data from the China Health and Retirement Longitudinal Study (CHARLS), which began in 2011. The study was carried out in accordance with the principles outlined in the Declaration of Helsinki, and received approval from the Ethics Committee of Peking University (IRB00001052-11015). Approval for data collection was obtained from the Ethical Review Committee at Peking University. All participants involved in the study have provided informed consent. The research team surveyed over 170,000 middle-aged and elderly community residents across 150 prefectures and 450 villages in China using multistage probability sampling. The primary survey was conducted in 2011 (Wave 1), followed by Wave 2, 3 and 4 in 2013, 2015, and 2018, respectively. Owing to the availability of the uric acid number, information from waves 1 and 3 was used in this investigation. Inclusion criteria were: (a) age ≥45 years old; (b) absence of renal disease and HUA; (c) no missing or abnormal data on BMI, WC, HDL-c, and TG; (d) completion of a questionnaire and blood sample collection; (e) successful follow-up until wave 3. Therefore, 4268 participants were eligible for analysis (Fig. 1).

2.2. Data collection and definitions of variations

Demographic information (age, sex, marital status, education, and residence), lifestyle factors (drinking status and smoking history), and risk factors (hypertension, diabetes, cardiovascular disease, and dyslipidemia) were assessed using questionnaires. Where marital status is classified as not married and currently married, educational level as illiterate, primary school and below, middle school and above, residence as rural and urban, drinking status as non-drinker and drinker. The question, “Have you been diagnosed with Hypertension/Dyslipidemia/Diabetes by a doctor?” is used to determine whether a volunteer has been diagnosed with the corresponding diseases. Trained nurses collected 8 ml blood samples from volunteers. The plasma was immediately transported to Beijing at −20 °C and stored at −70 °C for testing at the Capital Medical University laboratory, where fasting blood glucose (FBG), TG, and HDL-c concentrations were determined (Zhao et al., 2014).

This study used serum uric acid values of 420 μmol/l for men and 360 μmol/l for women to characterize HUA (Zhao et al., 2014). BMI was calculated as weight (kg) divided by height squared (m^2). Hypertension was defined as systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg (Liu, 2020). FBG levels of 126 mg/dL (7.0 mmol/L) or higher and a Hemoglobin A1c of 6.5 % or above indicated diabetes(Kahn, 2005). CVD was identified in participants who self-reported having a heart attack or stroke.

The VAI index was calculated as follows(Amato et al., 2010):

(1) Males: Visceral adiposity index = (waist circumference (cm)/(39.68+(1.88 × BMI))) × (TG (mmol/l)/1.03) × (1.31/HDL-c (mmol/l)).
(2) Females: Visceral adiposity index = (waist circumference (cm)/(36.58 + (1.89 × BMI))) × (TG (mmol/l)/0.81) × (1.52/HDL-c (mmol/l)).

The CVAI (Chinese visceral adiposity index) index was calculated as follows (Wan et al., 2020):

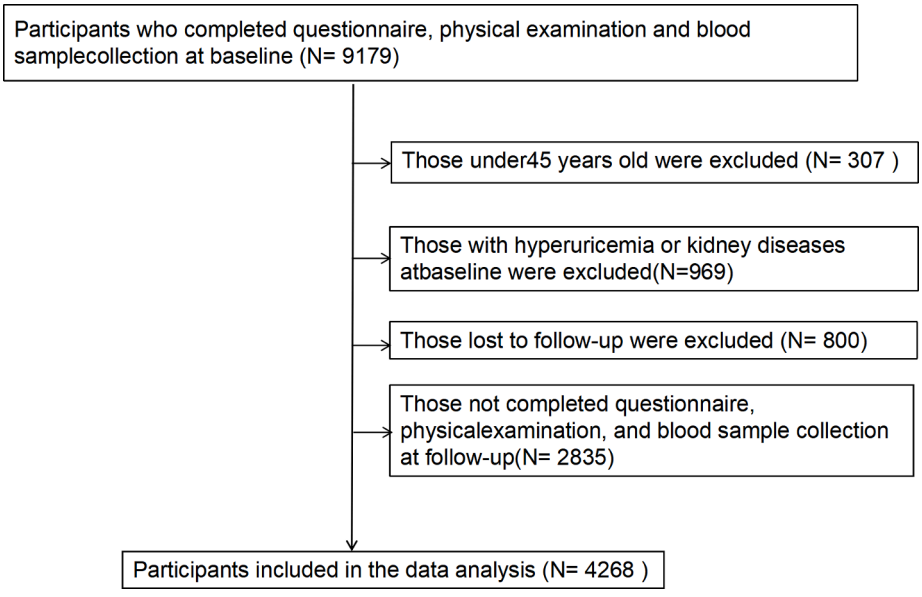

Fig. 1. Flow chart for selection of study population from the database of China Health and Retirement Longitudinal Study.

(1) Males: CVAl = -267.93 + 0.68 × age + 0.03 × BMI+4.00 × waist circumference (cm) + 22.00 × lgTG (mmol/l) −16.32 × HDL-C (mmol/l).
(2) Females: CVAI=-187.32 + 1.71 × age + 4.23 × BMI+1.12 × waist circumference (cm) + 39.76 × lgTG(mmol/l) −11.66 × HDL-C (mmol/l).

The lipid accumulation product was calculated using the following formula(Kahn, 2005):

(1) Males: Lipid accumulation product = (waist circumference (cm)-65) × TG (mmol/l).
(2) Females: Lipid accumulation product = (waist circumference (cm)-58) × TG (mmol/l).

People were categorized into two groups (high or low) based on the critical value determined by the study of restricted cubic spline curves to examine the changes in VAI, CVAIand LAP throughout the follow-up. The cutoff values were set at 1.57 (for VAI), 27.25 (for LAP) and 92.77 (for CVAI). Four patterns were identified in each measure's change from the follow-up period of 2011 to 2015: 1) low-low: persistently below the critical value; 2) low-to-high: low levels in 2011 that increased to high levels over time; 3) high to low: high levels in 2011 that decreased over time; and 4) high-high: high levels that persisted during the follow-up.

2.3. Statistical analysis

Continuous variables were described as mean (SD) and categorical variables as frequency (percentage). The normality of the data was verified using the Anderson–Darling test. Multivariable logistic regression was used to estimate the odds ratio (OR) and 95 % confidence interval (CI) of the associations between VAI, LAP, CVAI and HUA. The area under curve (AUC) was calculated using receiver operating characteristic (ROC) curve analysis, and the predictive ability of different obesity indices for HUA was compared. The predictors obtained through multivariable logistic regression were selected to construct a nomogram using the "rms" packages in R software. Restrictive cubic spline regression was used for testing nonlinear associations between the VAI/LAP/CVAI and HUA. Additionally, we classified visceral adipose accumulation patterns into four types: maintaining low levels, maintaining high levels, transitioning from low to high levels, transitioning from high to low levels, and investigating the longitudinal relationship between index accumulation and HUA incidence. We calculated the OR for the other three groups using multivariable logistic regression with the low-low group as a reference. Analyses were stratified according to sex (male or female). A significant difference was indicated by a *P*-value less than 0.05. All data analyses were conducted using the R statistical software (version 4.2.1).

3. Results

3.1. Characteristics of the cohort study

The subjects were categorized based on the occurrence of HUA during the follow-up period, with an evaluation of the baseline data for individuals in the two groups detailed in Table 1. In total 4268 participants (male: 44.96 %, female: 55.04 %; mean age: 58.47±8.58 years) were included in the study. Compared to healthy participants, patients with HUA were older, had a higher BMI, were more likely to drink, and had a higher prevalence of CVD, hypertension, and dyslipidemia.

3.2. Association of the CVAI, VAI and LAP, with HUA risk

As VAI, LAP and CVAI levels increased, a linear trend towards a higher probability of HUA was observed (all P for trend <0.001) in

Table1
Demographic, socioeconomic, and health characteristics of Chinese individuals, aged ≥45 years, stratified by prevalence of hyperuricemia, from 2011 to 2015.

Characteristics	Total	Hyperuricemia		p
		No	Yes	
Number, n (%)	4268(100.00)	3853 (90.28)	415(9.72)	–
Age (years, mean ± SD)	58.47±8.58	58.32±8.50	59.86±9.18	<0.001
Sex, n (%)				
Male	1919(44.96)	1711 (44.41)	208(50.12)	0.029
Female	2349(55.04)	2142 (55.59)	207(49.88)	
Residence, n (%)				
Rural	2928(68.60)	2659 (69.01)	269(64.82)	0.09
Urban	1340(31.40)	1194 (30.99)	146(35.18)	
Education status, n (%)				
Illiterate	1218(28.54)	1108 (28.76)	110(26.51)	0.536
Primary school and below	2680(62.79)	2415 (62.68)	265(63.86)	
Middle school and above	370(8.67)	330(8.56)	40(9.64)	
Marital status, n (%)				
Not married	3799(89.01)	3433 (89.10)	366(88.19)	0.632
Currently married	469(10.99)	420(10.90)	49(11.81)	
Smoking history, n (%)				
Non-smoker	2656(62.23)	2411 (62.57)	245(59.04)	0.079
Smoker	1612(37.77)	1442 (37.43)	211(40.96)	
Drinking status, n (%)				
Non-drinker	2664(62.42)	2433 (63.15)	231(55.66)	0.008
Drinker	1604(37.58)	1420 (36.85)	184(44.34)	
Hypertension, n (%)				
No	2601(60.94)	2423 (62.89)	178(42.89)	<0.001
Yes	1667(39.06)	1430 (37.11)	237(57.11)	
Diabetes mellitus, n (%)				
No	3589(84.09)	3251 (84.38)	338(81.45)	0.139
Yes	679(15.91)	602(15.62)	77(18.55)	
Cardiovascular disease, n (%)				
No	3714(87.02)	3377 (87.65)	337(81.20)	<0.001
Yes	554(12.98)	476(12.35)	78(18.80)	
Dyslipidemia, n (%)				
No	3871(90.70)	3516 (91.25)	355(85.54)	<0.001
Yes	397(9.30)	337(9.50)	60(14.45)	
BMI, kg/m2, mean ± SD	23.57±3.58	23.44±3.53	24.78±3.76	<0.001
VAI, mean ± SD	1.48(0.88,2.40)	1.43(0.86, 2.44)	2.07(1.07, 3.47)	<0.001
CVAI, mean ± SD	91.70 (65.98,121.40)	89.79 (64.77, 118.71)	113.69 (84.99, 139.83)	<0.001
LAP, mean ± SD	26.78 (14.51,46.80)	25.92 (14.00, 44.64)	39.20 (21.14, 69.84)	<0.001

Note: SD standard deviation, BMI body mass index, VAI visceral adiposity index, CVAI Chinese visceral adiposity index, LAP lipid accumulation product. The *p*-values of continuous variables are derived from the wilcoxon rank sum test, the *p*-values of categorical variables are derived from chi-square test.

multivariable logistic regression (Model 3). Besides, participants with VAI in the second to forth quartile were at higher risk of HUA than those in the first quartile (OR 1.38, 95 % CI 0.98–1.95; OR 1.30, 95 % CI 0.92–1.85 and OR 2.33, 95 % CI 1.66–3.30). Using LAP, the risk of HUA in the second to fourth quartiles was considerably higher than in the first quartile (OR 1.30, 95 % CI 0.91–1.87; OR 1.36, 95 % CI 0.94–1.98; OR 2.14, 95 % CI 1.44–3.19). Using CVAI, the risk of HUA in the second to forth quartiles was considerably higher than in the first quartile (OR 1.19, 95 % CI 0.82–1.73; OR 1.48, 95 % CI 1.01–2.16; OR 1.93, 95 % CI 1.24–3.02) (Table 2). Fig. S1 shows the relationships among VAI, LAP, CVAI and HUA stratified by sex. Following the results of multivariable binary logistic regression analysis, a nomogram was created utilizing four to five independent predictive variables for HUA (Figs. S2 and S3). Fig. S2 illustrates that the total score on the nomogram ranges from 0 to 180, with HUA risk probabilities falling between 0.05 and 0.8.

3.3. The ROC curves of CVAI, VAI and LAP for HUA

Fig. 2 illustrates the ROC curves and the AUC values for CVAI, VAI and LAP in the prediction of HUA during four-year follow up. The AUC value for CVAI (0.641) was somewhat higher than that for VAI (0.604) and LAP (0.628) according to the ROC curve analysis, and the intergroup difference was significant ($P < 0.001$), demonstrating that CVAI has a higher predictive ability than VAI or LAP for incident HUA (Fig. 2).

3.4. Restricted cubic spline regression

Restricted cubic splines were used to model and show the association between VAI, LAP, CVAI and HUA in the participants (Fig. 3). This study discovered nonlinear associations between VAI, LAP and CVAI after controlling for several factors (all P for nonlinearity were <0.001). At LAP levels <27.25, the risk of HUA remained relatively steady but subsequently began to rise quickly. With a cutoff value of 1.57, this study observed a statistically significant linear relationship between the risk of HUA and increasing VAI. With a cutoff value of 92.77, this study observed a statistically significant linear relationship between the risk of HUA and increasing CVAI.

3.5. Association between transition of visceral fat indicators and HUA

When calculating the cumulative incidence of HUA for different transition patterns, maintaining high patterns (VAI, LAP or CVAI) resulted in the highest cumulative incidence (Table 3). Populations with high-low VAI/CVAI patterns had a cumulative incidence similar to those with low–high VAI/CVAI patterns. Populations with low–high LAP patterns have a higher cumulative incidence than those with high-low patterns. Additionally, subgroup analyses indicated that maintaining high-level patterns of VAI, LAP and CVAI increased the risk of HUA in all participants compared with maintaining a low-level pattern (all $P < 0.05$), with higher adjusted ORs for females than males (Fig. S4).

4. Discussion

In a large-scale prospective cohort study involving older Chinese adults, we observed a positive association between visceral fat indices (including VAI LAP and CVAI) and the risk of HUA. The findings of this study indicate that transitioning from low to high visceral fat levels may contribute to an increased HUA risk. Furthermore, this analysis using ROC curves revealed that CVAI exhibited superior predictive capability for HUA compared to VAI/LAP. Additionally, visceral fat indices were related to the risk of HUA in all participants, with higher adjusted ORs for females. This study highlights the potential of judicious management of CVAI as an effective preventive measure against the onset or progression of HUA.

Although previous research has established a connection between the VAI, LAP, and CVAI indices and an elevated risk of diabetes, hypertension, or cardiovascular disease(Kouli et al., 2017, Wan et al., 2020), few studies have examined the association between visceral adipose accumulation and HUA. This study explored this area and revealed that a higher CVAI exhibited a more pronounced association with a higher risk of HUA than VAI and LAP.

Takahashi et al. and Matsuura et al. conducted earlier studies that examined the effect of subcutaneous fat accumulation measured by CT scans on uric acid metabolism. However, their findings were limited in their applicability owing to small sample sizes and the inclusion of

Table 2
Odds ratios of hyperuricemia associated with CVAI, VAI and LAP among Chinese individuals aged ≥45 years, from 2011 to 2015.

Characteristics	Cases (%)	OR (95 % CI)			
		unadjusted model	Model 1	Model 2	Model 3
VAI					
Q1	66 (6.2)	1	1	1	1
Q2	88 (8.2)	1.36(0.98,1.90)	1.50(1.07,2.10)	1.50(1.07,2.10)	1.38(0.98,1.95)
Q3	94 (8.8)	1.47(1.06,2.04)	1.64(1.17,2.31)	1.64(1.17,2.31)	1.30(0.92,1.85)
Q4	167(15.7)	2.81(2.10,3.82)	3.16(2.28,4.40)	3.16(2.28,4.40)	2.33(1.66,3.30)
P for trend		<0.001	<0.001	<0.001	<0.001
VAI change, per SD increase	415 (9.7)	1.23(1.15,1.33)	1.26(1.17,1.36)	1.23(1.13,1.33)	1.19(1.10,1.29)
CVAI					
Q1	58(5.4)	1	1	1	1
Q2	72(6.7)	1.26(0.88,1.80)	1.33(0.93,1.92)	1.28(0.89,1.85)	1.19(0.82,1.73)
Q3	107(10.0)	1.94(1.40,2.72)	2.05(1.47,2.89)	1.84(1.31,2.60)	1.48(1.01,2.16)
Q4	178(16.7)	3.48(2.57,4.78)	3.52(2.58,4.88)	2.88(2.08,4.03)	1.93(1.24,3.02)
P for trend		<0.001	<0.001	<0.001	<0.001
CVAI change, per SD increase	415(9.7)	1.62(1.46,1.81)	1.60(1.43, 1.79)	1.46(1.30, 1.64)	1.19(1.02, 1.40)
LAP					
Q1	61 (5.7)	1	1	1	1
Q2	84 (7.9)	1.41(1.00,1.99)	1.59(1.13,2.26)	1.53(1.08,2.17)	1.30(0.91,1.87)
Q3	97(9.1)	1.65(1.19,2.31)	1.98(1.41,2.80)	1.77(1.25,2.51)	1.36(0.94,1.98)
Q4	173(16.2)	3.19(2.36,4.36)	4.02(2.93,5.59)	3.36(2.41,4.73)	2.14(1.44,3.19)
P for trend		<0.001	<0.001	<0.001	<0.001
LAP change, per SD increase	415(9.7)	1.35(1.25,1.47)	1.39(1.28,1.52)	1.34(1.22,1.47)	1.21(1.09,1.34)

Note: Model 1 was adjusted for age and sex.
Model 2 was further adjusted for educational level, marital status, residence, smoking history, and drinking status based on Model 1.
Model 3 was further adjusted for all the factors in Model 2, including cardiovascular disease, diabetes, hypertension, and dyslipidemia.
SD standard deviation, OR odds ratio, CI confidence interval, Q1 first quartile, Q2 second quartile, Q3 third quartile, Q4 fourth quartile, VAI visceral adiposity index, CVAI Chinese visceral adiposity index, LAP lipid accumulation product.

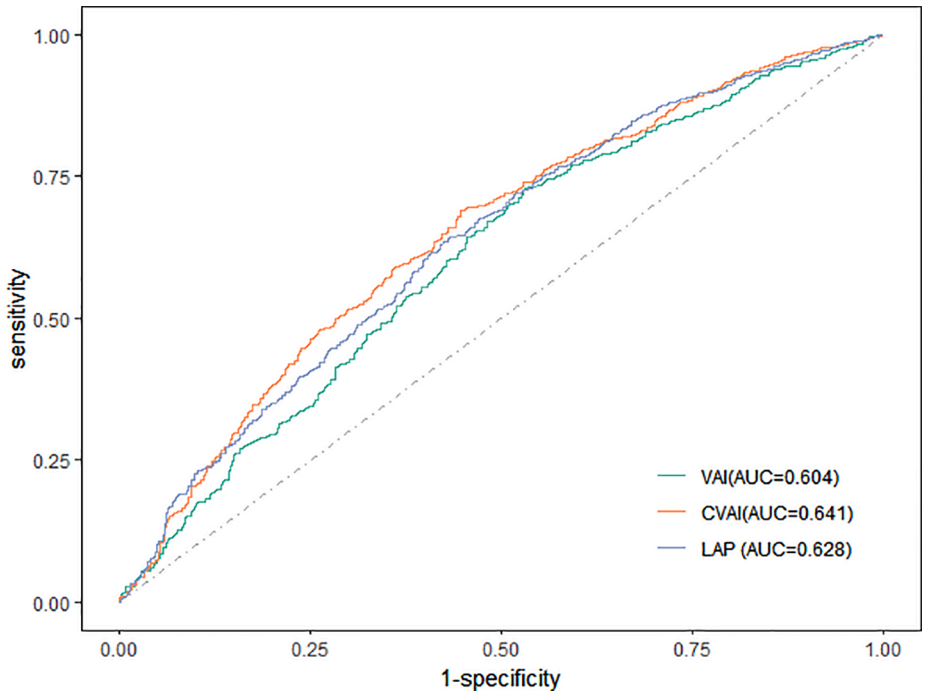

Fig. 2. ROC curves comparing VAI, LAP and CVAI for incident hyperuricemia among Chinese individuals aged ≥45 years, from 2011 to 2015. Note: VAI visceral adiposity index, CVAI Chinese visceral adiposity index, LAP lipid accumulation product.

participants primarily from outpatient and obese populations. In a separate cross-sectional study involving 862 men, excessive subcutaneous and hepatic fat observed on CT scans exhibited a dose-dependent association with HUA. A similar conclusion was drawn in another study involving patients with polycystic ovary syndrome (Zhang et al., 2021). However, the participants in these studies might limit the generalizability of their findings.

This study used VAI, LAP and CVAI to assess visceral fat accumulation. Based on age, WC, BMI, TG, and HDL-C, the CVAI has been proposed as a practical and reliable diagnostic tool for evaluating visceral adipose tissue. Its accuracy and applicability in the diagnosis of visceral fat are well established. One of the strengths of this study is its longitudinal design, which helps elucidate the relationship between visceral fat and HUA and allows for predictions about future HUA based on VAI, LAP and CVAI values. Additionally, incorporating CVAI as a predictor of HUA could enhance its use in screening metabolic and cardiovascular diseases in large-scale studies.

Based on previous studies, the mechanism by which visceral fat causes HUA is mainly a strong association between the accumulation of visceral adipose tissue and excessive UA production or a reduction in extra renal uric acid excretion (Yamada et al., 2016). The accumulation of visceral fat can lead to the backflow of free fatty acids to the liver, stimulating synthesis and resulting in hypertriglyceridemia. Furthermore, excess free fatty acids may promote UA overproduction via the pentose phosphate pathway, which is involved in purine synthesis. These studies identified a significant link between TG and uric acid levels. Consistent with these findings, Huan et al. observed that patients with HUA had significantly higher WC, BMI, hypertension, TC, TG, and low-density lipoprotein cholesterol (LDL-C) levels and significantly lower HDL-c levels than individuals without HUA (Matsuura et al., 1998).

These findings are consistent with earlier studies indicating that the association between visceral adipose indices and HUA is more prominent in females (Wang et al., 2022). This difference may be because women have unique sex hormones and adipokines that predispose them to abdominal obesity than men(Kodama et al., 2013). Given the higher fat mass observed in healthy women than in men, circulating free fatty acid levels and intramuscular fat content also increase. These factors could potentially enhance susceptibility to VAI, LAP and CVAI. Consequently, visceral adipose indices may be more useful for identifying women who develop HUA.

Interestingly, when conducting a sex analysis, we found that women with high-low LAP patterns exhibited a higher cumulative incidence compared to those with low–high patterns. This may be due to the influence of sex steroid hormones and glucose homeostasis on the body. Healthy women have a higher fat content than men, and the levels of free fatty acids in the bloodstream and fat content within muscles are also higher in women, which may lead to higher UA levels in females, thereby increasing the risk of hyperuricemia (Blaak, 2008, Fuente-Martín et al., 2013, Mauvais-Jarvis, 2015). This sex contrast is similar to the findings of previous studies by Framingham and Wei Zhou et al., whose data revealed that women, compared to men, are more likely to have higher TG levels, thus increasing the risk of cardiovascular diseases and diabetes (Castelli, 1986, Ho et al., 2015).

Similarly, many studies have indicated a close association between HUA and chronic diseases such as hypertension, diabetes, and dyslipidemia. Lowering blood uric acid levels can prevent cardiovascular diseases (Wang et al., 2022, King et al., 2018, Copur et al., 2022). A Mendelian randomization study identified a causal association between uric acid and hypertension (Parsa et al., 2012). Importantly, elevated serum uric acid levels predict the development of hypertension, fatty liver, and diabetes (Kodama et al., 2009, Kuwabara et al., 2023, Sanchez-Lozada et al., 2020, Li et al., 2022).

This research found that VAI, LAP and CVAI were significantly associated with HUA risk in people. In the future, focusing on using these indices to predict HUA development in women and individuals with chronic diseases would be beneficial.

5. Strengths and limitations

This study had several strengths. First, the data were obtained from a representative population-based study, enhancing the generalizability of the findings to a broader population. Second, this study used the simple surrogate markers VAI, CVAI and LAP to assess HUA risk in

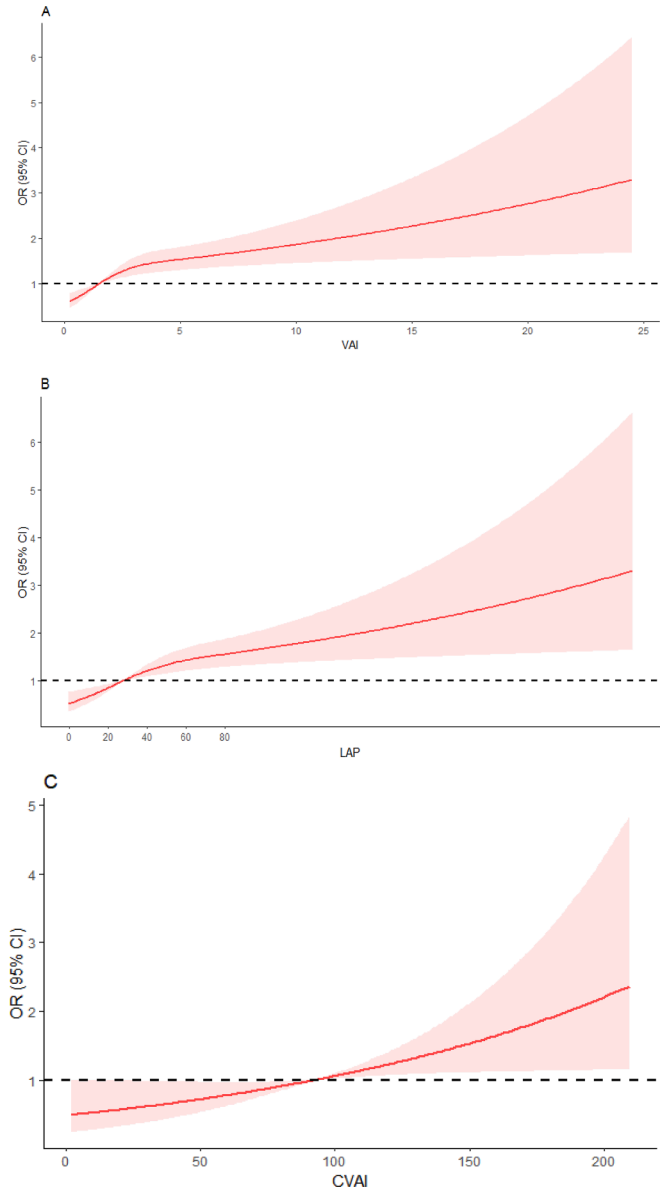

Fig. 3. Association of the VAI (A), LAP (B) and CVAI (C) with hyperuricemia risk, among Chinese individuals aged ≥45 years, from 2011 to 2015. Data were fitted by logistic regression models of the restricted cubic spline adjusting for age, sex, educational level, marital status, residence, smoking history, drinking status, cardiovascular disease, diabetes, hypertension, and dyslipidemia. Note: VAI visceral adiposity index, CVAI Chinese visceral adiposity index, LAP lipid accumulation product, OR odds ratio, CI confidence interval.

Chinese adults. These markers are practical and cost-effective, making them suitable for clinic and epidemiological settings. Additionally, the study explored the relationship between visceral adipose indices and the incidence of HUA and indicated that reducing VAI, CVAI or LAP might help mitigate HUA risk. Furthermore, it was observed that CVAI exhibited a better predictive ability for HUA than VAI and LAP.

Despite these strengths, this study has some limitations. First, although various confounding variables were adjusted for, the influence of diet and medication could not be completely ruled out, potentially affecting the development of HUA. Second, as this study included only Chinese adults, the results may not directly apply to other ethnic populations. It is important to interpret these findings within the context of the study population.

Table 3
Risk of incident hyperuricemia according to different visceral fat indicator transitions among Chinese adults, aged ≥45 years.

Transition types	Cases (%)	OR (95 % CI)			
		unadjusted model	Model 1	Model 2	Model 3
VAI					
Low-Low	98 (6.7)	1	1	1	1
Low-High	58 (8.4)	1.29(0.91, 1.80)	1.55 (1.09, 2.18)	1.45 (1.02, 2.05)	1.28 (0.90, 1.82)
High-Low	35 (8.0)	1.22(0.81, 1.81)	1.38 (0.91, 2.05)	1.31 (0.86, 1.95)	1.08 (0.70, 1.62)
High-High	224 (13.3)	2.14(1.67, 2.76)	2.74 (2.10, 3.60)	2.37 (1.80, 3.14)	1.77 (1.33, 2.38)
CVAI					
Low-Low	74 (4.9)	1	1	1	1
Low-High	56 (8.7)	1.85(1.29, 2.65)	1.88 (1.31, 2.70)	1.74 (1.21, 2.50)	1.54 (1.05, 2.23)
High-Low	13 (8.5)	1.79(0.93, 3.21)	1.72 (0.89, 3.09)	1.58 (0.82, 2.85)	1.31 (0.67, 2.40)
High-High	272 (13.8)	3.09(2.38, 4.06)	3.14 (2.40, 4.15)	2.63 (2.00, 3.51)	1.84 (1.30, 2.62)
LAP					
Low-Low	104 (6.3)	1	1	1	1
Low-High	42 (8.5)	1.38(0.94, 1.99)	1.61 (1.09, 2.34)	1.50 (1.01, 2.19)	1.27 (0.85, 1.87)
High-Low	14 (5.6)	0.88(0.47, 1.51)	0.98 (0.53, 1.69)	0.94 (0.51, 1.63)	0.76 (0.40, 1.33)
High-High	255 (13.7)	2.37(1.87, 3.02)	2.86 (2.23, 3.70)	2.42 (1.86, 3.15)	1.69 (1.24, 2.29)

Note: The definition of transition types during follow-up was as follows: group maintaining a low level, below the cutoff value during the follow-up period; group from low to high level, below the cutoff value in 2011, turned to a high level during follow-up; group from high to low, high level in 2011 turned to low level during the follow-up period; and group maintaining high level, maintaining high level during the follow-up period.
Model 1 was adjusted for age and sex.
Model 2 was further adjusted for educational level, marital status, residence, smoking history, and drinking status based on Model 1.
Model 3 was further adjusted for all the factors in Model 2, including cardiovascular disease, diabetes, hypertension, and dyslipidemia.
OR odds ratio, CI confidence interval, VAI visceral adiposity index, CVAI Chinses visceral adiposity index, LAP lipid accumulation product.

6. Conclusions

In conclusion, VAI, LAP and CVAI are valuable predictors of the incidence of HUA in the Chinese population aged ≥45 years and exhibit comparable performance. The transitions in the status of the three predictors and the probability of HUA showed a strong association. Furthermore, CVAI had a greater ability to identify HUA based on visceral fat. Therefore, long-term monitoring of CVAI changes and early control of lipid metabolism could establish a theoretical basis for HUA prevention among Chinese people (≥45 years old). This study indicates that CVAI should be tightly controlled to achieve a comprehensive HUA benefit.

Institutional Review Board Statement: The study was carried out in accordance with the principles outlined in the Declaration of Helsinki, and received approval from the Ethics Committee of Peking University (IRB00001052-11015). Approval for data collection was obtained from

the Ethical Review Committee at Peking University, which is renewed on a yearly basis.

Informed Consent Statement: All participants involved in the study have provided informed consent.

CRediT authorship contribution statement

Yutong Han: Methodology, Formal analysis, Data curation. **Jiang Li:** Methodology, Investigation, Data curation. **Wendi Bai:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgments

The authors would like to express their gratitude to the National School of Development at Peking University for granting access to the CHARLS data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102843.

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