Association Between Chinese Visceral Adiposity Index and Cardiometabolic Multimorbidity in Population Aged ≥ 60 Years: A Cross-Sectional Study Postprint

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Abstract

Background As China' s population aging intensifies and the phenomenon of multimorbidity becomes increasingly common, the high-risk characteristics of cardiovascular metabolic multimorbidity (CMM) have emerged as a critical research area. The Chinese Visceral Adiposity Index (CVAI), as a novel indicator for predicting cardiovascular disease, currently has an unclear relationship with CMM.

Objective To investigate the relationship between CVAI and CMM risk in populations aged $ $60 years, and to evaluate the potential role of CVAI in CMM prevention and management.

Methods Based on data from 60,029 participants in the Anhui Province Cardiovascular Disease High-risk Population Early Screening and Comprehensive Intervention Project from 2017 to 2021, we analyzed demographic information, cardiovascular health status, physical examination and laboratory parameters, and calculated CVAI. Participants were stratified into four groups according to CVAI quartiles, baseline characteristics were compared among the four groups, and multivariate logistic regression analysis was employed to explore the association between CVAI and high CMM risk in different gender populations. Restricted cubic spline (RCS) curves were used to assess the relationship between CVAI and CMM across genders, with OR=1 established as the threshold.

Results Among the 60,029 participants, 27,203 were male and 32,826 were female. Across CVAI quartile groups in different genders, differences in age, smoking, alcohol consumption, rural residence, high school education, BMI, mean arterial pressure (MAP), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), fasting plasma glucose (FPG), and proportions

of diabetes, stroke, hypertension, and ischemic heart disease were all statistically significant (P>0.05). In females, differences in the proportion of hypertension medication history across CVAI quartile groups were statistically significant (P>0.05). Multivariate logistic regression analysis revealed that compared with the T1 (F1) group, the T2–T4 (F2–F4) groups exhibited increased CMM risk (P<0.05). After full adjustment for confounding factors, the T4 (F4) group demonstrated the highest CMM risk in both males (OR=2.335, 95%CI=1.741–3.180, P<0.001) and females (OR=2.075, 95%CI=1.678–2.686, P<0.001). Comparisons of CMM risk between genders within each group showed no statistically significant differences (P>0.05). After controlling for different confounding factors, RCS curves indicated a non-linear relationship between CVAI and CMM risk in males, with an OR=1 threshold of 94.75; in females, CVAI showed a linear relationship with CMM risk, with an OR=1 threshold of 114.87.

Conclusion Elevated CVAI may be closely associated with CMM risk, and the predictive efficacy of CVAI for CMM is consistent across genders. Special attention should be directed toward males with CVAI exceeding 94.75 and females exceeding 114.87 to reduce CMM risk.

Full Text

A Cross-sectional Study on the Relationship between the Chinese Visceral Adiposity Index and Cardiometabolic Multimorbidity in Individuals Aged 60 and Above

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Abstract

Background
With the intensification of population aging and the increasing prevalence of multimorbidity in China, the high-risk characteristics of cardiometabolic multimorbidity (CMM) have become a critical research focus. The Chinese Visceral Adiposity Index (CVAI) has emerged as a novel indicator for predicting cardiovascular disease, yet its relationship with CMM remains unclear.

Objective
This study aims to investigate the relationship between CVAI and CMM risk

among individuals aged 60 years and above, and to evaluate the potential role of CVAI in CMM prevention and management.

Methods
Based on data from 60,029 participants in the Early Screening and Comprehensive Intervention Program for High-risk Cardiovascular Populations in Anhui Province (2017-2021), we analyzed demographic information, cardiovascular health status, physical examination findings, and laboratory indicators to calculate CVAI values. Participants were stratified into four groups according to CVAI quartiles. Baseline characteristics were compared across groups, and multivariate logistic regression analysis was employed to examine the association between CVAI and high CMM risk in different gender groups. Restricted cubic spline (RCS) curves were used to assess the gender-specific relationship between CVAI and CMM, with OR=1 established as the threshold.

Results
Among the 60,029 participants (27,203 males and 32,826 females), significant differences were observed across CVAI quartiles for age, smoking, alcohol consumption, rural residence, high school education, BMI, mean arterial pressure (MAP), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), fasting plasma glucose (FPG), and prevalence of diabetes, stroke, hypertension, and ischemic heart disease ($P<0.05$). In women, the proportion with hypertension medication history also differed significantly across quartiles ($P<0.05$). Multivariate logistic regression revealed that compared with the lowest quartile group (T1 for men, F1 for women), CMM risk increased significantly in the higher quartile groups ($P<0.05$). After full adjustment for confounders, the highest quartile group exhibited the greatest CMM risk in both men (OR=2.335, 95%CI=1.741-3.180, $P<0.001$) and women (OR=2.075, 95%CI=1.678-2.686, $P<0.001$). No significant gender differences were found in CMM risk across groups ($P>0.05$). RCS analysis after controlling for confounders showed a non-linear relationship between CVAI and CMM risk in men, with an OR=1 threshold of 94.75, whereas women demonstrated a linear relationship with a threshold of 114.87.

Conclusion
Elevated CVAI levels are strongly associated with increased CMM risk, with consistent predictive efficacy across genders. Special attention should be paid to men with CVAI exceeding 94.75 and women exceeding 114.87 to effectively reduce CMM risk.

Keywords: Cardiometabolic multimorbidity; Chinese visceral adiposity index; Visceral obesity indicator; Obesity; Anhui Province; Cross-sectional study

Introduction

Cardiovascular and metabolic diseases, including cardiovascular disease, diabetes, and stroke, pose significant threats to human health, particularly when these conditions coexist. In recent years, rising global obesity rates have been accompanied by increased incidence of cardiometabolic diseases [1]. Cardiometabolic multimorbidity (CMM) is defined as the concurrent presence of at least two of the following conditions: type 2 diabetes, stroke, and ischemic heart disease, representing one of the most dangerous forms of chronic disease multimorbidity [2].

Obesity is widely recognized as the most important risk factor for cardiometabolic multimorbidity. A pooled analysis of 16 cohort studies from Europe and the United States found that elevated BMI was associated with increased risk of various cardiometabolic disease combinations [3]. Visceral fat distribution serves as an independent predictor of cardiometabolic diseases, and reducing excessive visceral adiposity is crucial for lowering cardiometabolic disease risk [4]. To accurately assess visceral fat in Chinese populations, researchers developed the Chinese Visceral Adiposity Index (CVAI) based on age, BMI, waist circumference, triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C) data from Chinese populations [5].

While several studies have examined the association between CVAI and individual cardiometabolic diseases, research specifically investigating the relationship between CVAI and CMM remains limited. Notably, studies examining gender differences in CVAI and CMM risk among elderly populations are particularly scarce. Therefore, this study aims to explore gender-specific differences in the relationship between CVAI and CMM risk among individuals aged 60 years and above, and to validate the utility of CVAI as an early warning indicator for CMM.

Methods

1.1 Study Population

Participants were selected from the Early Screening and Comprehensive Intervention Program for High-risk Cardiovascular Populations in Anhui Province (2017–2021). This program surveyed community residents undergoing physical examinations across 12 counties and cities in Anhui Province, yielding 60,029 datasets. Inclusion criteria were: age 60–75 years and residence in the area for at least six months prior to screening. Exclusion criteria included missing data on age, smoking, alcohol consumption, marital status, total cholesterol (TC), TG, fasting plasma glucose (FPG), HDL-C, or other baseline information.

The study adhered to principles of informed consent and voluntary participation, with all participants providing written informed consent. The study protocol

was approved by the Ethics Committee of Suzhou Hospital Affiliated to Anhui Medical University (Approval No. A2022033).

1.2 Data Collection and Definitions

1.2.1 General Data Collection

Demographic information, physical examination findings, and laboratory indicators were collected and measured by professionally trained medical staff. Demographic information included gender, age, smoking and alcohol consumption history, and cardiovascular disease history. Hypertension medication history was defined as use of antihypertensive drugs (including traditional Chinese or Western medicine) within the preceding two weeks. Physical examinations included blood pressure, height, and weight measurements. Laboratory indicators comprised fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C). All participants provided 6 mL fasting venous blood samples in the morning after an overnight fast for biochemical testing.

1.2.2 CVAI Calculation

CVAI was calculated using gender-specific formulas [5]:
For men: CVAI = -267.93 + 0.68 × age (years) + 0.03 × BMI + 4.00 × WC (cm) + 22.00 × $\log_{10}$[TG (mmol/L)] - 16.32 × HDL-C (mmol/L)
For women: CVAI = -187.32 + 1.71 × age (years) + 4.32 × BMI + 1.12 × WC (cm) + 39.76 × $\log_{10}$[TG (mmol/L)] - 11.66 × HDL-C (mmol/L)

Participants were stratified by gender into male (n=27,203) and female (n=32,826) groups, then further divided by CVAI quartiles:
Men: T1 (1.61-65.69, n=6,801), T2 (65.71-94.74, n=6,801), T3 (94.75-122.73, n=6,801), T4 (122.74-226.54, n=6,800)
Women: F1 (10.57-95.32, n=8,207), F2 (95.33-114.97, n=8,207), F3 (114.98-134.88, n=8,206), F4 (134.89-226.50, n=8,206)

1.2.3 Definitions

CMM was defined as the coexistence of more than one of the following conditions: type 2 diabetes, stroke, and ischemic heart disease [2]. CMM components were defined as the number of diseases comprising CMM.

1.3 Statistical Analysis

Data analysis was performed using R version 4.1.4 and SPSS version 27.0. Normally distributed continuous variables were expressed as mean ± standard deviation and compared using one-way ANOVA. Non-normally distributed continuous variables were presented as median (P25, P75) and compared using the Kruskal-Wallis H test. Categorical variables were expressed as frequency (percentage) and compared using ^{2} tests, with trend tests and Bonferroni correction applied for multiple group comparisons.

Multivariate logistic stepwise regression analysis was used to examine the associ-

ation between CVAI (as both a continuous variable and by quartiles) and CMM. Z-tests were employed to identify differences in OR values between groups. Restricted cubic spline (RCS) curves were plotted to determine the cutoff point where OR=1. Statistical significance was set at P<0.05.

Results

2.1 Baseline Characteristics by Gender and CVAI Quartiles

In the male population, significant differences were observed across CVAI quartile groups for age, smoking, alcohol consumption, high school education, rural residence, BMI, MAP, TC, TG, HDL-C, FPG, CMM prevalence, and proportions of diabetes, stroke, hypertension, and ischemic heart disease (P<0.05). No significant differences were found in hypertension medication history across the four male groups (P>0.05) .

In the female population, significant differences were observed across CVAI quartile groups for age, smoking, alcohol consumption, high school education, rural residence, BMI, MAP, TC, TG, HDL-C, LDL-C, FPG, diabetes, stroke, hypertension, ischemic heart disease, and hypertension medication history (P<0.05) .

Across gender-specific CVAI quartile groups, the number of comorbidities increased with higher CVAI quartiles. Significant differences were found in CMM component counts of 0, 1, and 2 (P<0.05), while the number of participants with all three CMM components was too small to show statistical significance (P>0.05) .

2.2 Multivariate Logistic Regression Analysis of CMM Risk

Using CMM status as the dependent variable (yes=1, no=0) and CVAI quartile groups as the independent variable (with the lowest quartile group as reference: T1 for men, F1 for women), multivariate logistic stepwise regression analysis revealed:

Model 1 (unadjusted): Higher quartile groups showed increased CMM risk compared with the reference group in men (OR=1.740, 2.753, and 4.507 for T2-T4, respectively; P<0.05) and in women (OR=1.444, 2.141, and 3.200 for F2-F4, respectively; P<0.05). No significant gender differences were observed in CMM risk across groups (P>0.05).

Model 2 (adjusted for smoking, alcohol consumption, high school education, rural residence, TC, and glucose): Higher quartile groups showed increased CMM risk compared with the reference group in men (OR=1.153, 2.149, and 2.929 for T2-T4, respectively; P<0.05) and in women (OR=1.430, 1.896, and 2.562 for F2-F4, respectively; P<0.05). No significant gender differences were observed (P>0.05).

Model 3 (additionally adjusted for MAP, hypertension history, and hypertension medication): Higher quartile groups showed increased CMM risk compared with the reference group in men (OR=1.465, 1.855, and 2.335 for T2–T4, respectively; P<0.05) and in women (OR=1.309, 1.643, and 2.075 for F2–F4, respectively; P<0.05). No significant gender differences were observed (P>0.05) .

2.3 Gender Differences in CVAI-CMM Relationship and RCS Analysis

After controlling for confounding factors (smoking, alcohol consumption, high school education, rural residence, TC, glucose, MAP, hypertension history, and hypertension medication), RCS curves demonstrated a non-linear relationship between CVAI and CMM risk in men, with an OR=1 threshold of 94.75. In women, the relationship was linear, with an OR=1 threshold of 114.87 [Figure 1: see original paper].

Discussion

This study examined 60,029 elderly residents aged 60–75 years from the Anhui Province cardiovascular high-risk population cohort to systematically investigate the association between the visceral adiposity indicator CVAI and CMM. The results revealed significant differences in CMM prevalence across CVAI quartile groups (men: 1%, 1%, 2%, 4% for T1–T4, P<0.001; women: 1%, 1%, 2%, 3% for F1–F4, P<0.001). Notably, the prevalence of individual cardiometabolic diseases also increased synchronously with CVAI levels. Due to the small number of participants with all three CMM components across the four groups, no statistical significance was observed, which indirectly underscores the severe impact of CMM on healthy life expectancy in Chinese residents. A meta-analysis of 91 cohort studies demonstrated that developing all three CMM components by age 60 is associated with a 15-year reduction in life expectancy [6].

Visceral fat accumulation is an independent risk factor for cardiometabolic diseases. Compared with BMI, CVAI is a superior indicator for identifying cardiometabolic diseases in Chinese populations. A prospective population-based study demonstrated that CVAI is a highly effective predictor of cardiovascular disease among women in Southwest China [7]. Another large Chinese study showed that CVAI outperformed BMI and other anthropometric measures in predicting type 2 diabetes, suggesting it may be a reliable and applicable indicator for identifying high-risk populations [8]. Additionally, research has indicated a dose-response relationship between CVAI and risks of cardiovascular disease, heart disease, and stroke, with each standard deviation increase in CVAI associated with 17%, 12%, and 31% increased risk, respectively [9]. Our study extends these findings by demonstrating that CVAI is not only a predictor of individual cardiometabolic conditions but also effectively identifies individuals

at high risk for CMM.

After adjusting for all confounding factors, our study found that compared with the lowest quartile group, men in higher quartile groups had CMM risk ORs of 1.465, 1.855, and 2.335, respectively, while women in higher quartile groups had ORs of 1.309, 1.643, and 2.075, respectively. No significant gender differences were observed in OR values across CVAI quartile groups ($P>0.05$). Although limited research has examined gender differences, our findings demonstrate that CVAI serves as a consistent predictor of CMM risk in both men and women. These results align with existing literature. A cohort study of middle-aged and older Chinese adults reported significantly increased cardiometabolic multimorbidity risk among participants in higher CVAI quartiles compared with those in lower quartiles [10].

Notably, after controlling for hypertension history, mean arterial pressure, and hypertension medication in Model 3, the association between CVAI and CMM was attenuated, suggesting that hypertension may mediate or influence the effect of CVAI on CMM risk. Visceral fat directly affects blood pressure regulation by secreting pro-inflammatory factors (such as TNF-α and IL-6) and hormones (such as cortisol), leading to vasoconstriction and increased blood pressure, which ultimately elevates stroke and heart disease risk [11]. ZHANG et al. [12] also reported a stronger association between high CVAI quartiles and stroke risk among individuals with hypertension.

RCS analysis after controlling for confounders revealed that the OR=1 threshold for women was 114.87, with an overall linear relationship. As CVAI increased, CMM risk rose steadily, and this dose-dependent elevation persisted beyond the threshold. In men, the relationship was non-linear, with an OR=1 threshold of 94.78. CMM risk increased sharply before reaching 94.78, but the rate of increase plateaued thereafter. These findings suggest that women experience slower initial risk escalation with early visceral fat accumulation, but risk continues to rise in later stages, whereas men show rapid early risk increase that stabilizes after reaching a certain level. Consequently, women should prevent excessive weight and visceral fat gain, particularly in later life, while men require early intervention during initial visceral fat accumulation. These gender differences may be attributed to men' s adipose tissue being more susceptible to lipotoxicity and oxidative stress [13], while women' s adipose tissue exhibits higher energy expenditure and mitochondrial functional expression, demonstrating greater adaptability to metabolic stress [14]. Furthermore, men are more prone to arterial stiffening in old age, a direct consequence of visceral fat accumulation and chronic inflammatory responses [15]. Thus, as CVAI increases, men' s CMM risk rises rapidly at lower CVAI levels but plateaus at higher levels as vascular function deterioration reaches a limit. Wu et al. [16] also reported that early CVAI accumulation confers greater cardiovascular disease risk than later accumulation, emphasizing the importance of optimal CVAI control early in life.

However, this study has several limitations. First, although we utilized a well-

powered cross-sectional design to explore the association between CVAI and CMM, causal inference is precluded by the study design. Future research should employ causal inference methods such as Mendelian randomization or experimental designs to clarify the causal relationship. Second, due to database limitations, detailed information on participants' diet, precise physical activity, and sleep patterns were unavailable, potentially leading to unmeasured confounding. Finally, our sample was restricted to Anhui Province, which may introduce selection bias; multi-center studies across China are needed to validate our findings.

In conclusion, using multivariate logistic regression and RCS analysis, our study demonstrates that CVAI exhibits consistent predictive power for CMM risk across genders. Men require early intervention during initial visceral fat accumulation to prevent rapid risk escalation, while women should focus on preventing excessive weight and visceral fat gain, particularly in later life, to avoid significant CMM risk increases. In clinical practice, special attention should be paid to men with CVAI exceeding 94.75 and women exceeding 114.87, with proactive prevention and intervention strategies implemented for these high-risk individuals to effectively reduce CMM risk.

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