Correlation between Visceral Adiposity Index and Nocturnal Hypertension in Young and Middle-aged Chinese Adults: A Postprint

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Abstract

Background The Chinese visceral adiposity index (CVAI) is a novel obesity indicator that has been confirmed to be closely associated with prehypertension and hypertension; however, studies on the correlation between CVAI and nocturnal hypertension (NH) in young and middle-aged individuals are currently lacking. Objective To investigate the correlation between CVAI and NH in young and middle-aged individuals. Methods A total of 981 young and middle-aged patients with essential hypertension admitted to the Department of Hypertension, Fifth Affiliated Hospital of Xinjiang Medical University between February 2023 and September 2023 were enrolled as study subjects. General data, biochemical indicators, 24-hour ambulatory blood pressure monitoring results were collected, and CVAI was calculated. Patients were divided into a non-nocturnal hypertension (NNH) group (n=95) and a NH group (n=886) based on the presence or absence of concomitant NH. Differences in general data, biochemical indicators, 24-hour ambulatory blood pressure, and CVAI between the two groups were compared. Pearson correlation analysis was used to explore the correlation between CVAI and NH. Multivariate logistic regression analysis was employed to evaluate the influencing factors of NH in young and middle-aged individuals. Results The CVAI, 24-hour mean systolic and diastolic blood pressure, daytime mean systolic and diastolic blood pressure, nighttime mean systolic and diastolic blood pressure, and maximum systolic and diastolic blood pressure in the NH group were significantly higher than those in the NNH group (all $P<0.05$). Pearson correlation analysis revealed that CVAI was positively correlated with 24-hour mean systolic and diastolic blood pressure, daytime mean systolic and diastolic blood pressure, nighttime mean systolic and diastolic blood pressure, and maximum systolic blood pressure ($r=0.202$, 0.183, 0.200, 0.171, 0.168, 0.174, 0.132, 0.157, all $P<0.05$). Multivariate logistic regression analysis showed that after adjusting for confounding factors such as sex and age, high CVAI was an independent risk factor

for NH in young and middle-aged individuals (OR=1.009, 95%CI=1.002~1.016, P=0.014). According to CVAI quartiles, patients were divided into Q1 group (<103.5243, n=245), Q2 group (103.5243~129.7140, n=246), Q3 group (129.7140~156.2704, n=245), and Q4 group (>156.2704, n=245). The risks of nocturnal hypertension in Q2, Q3, and Q4 groups were 1.779 times (OR=1.779, 95%CI=1.002~3.157), 2.023 times (OR=2.023, 95%CI=1.061~3.858), and 3.053 times (OR=3.053, 95%CI=1.383~6.737) that of Q1 group, respectively. Subgroup analysis results demonstrated that the association between CVAI and NH was more pronounced in the overweight/obese population (BMI$ 24$kg/m2)($P =$ 0.021).$ConclusionCVAIisassociatedwiththeriskofNHoccurrenceinyoungandmiddle-agedindividuals,andthisassociationismoresignificantintheoverweight/obesepopulation(BMI$ \$24 kg/m2), representing a risk factor for NH development in this population.

Full Text

Preamble

Correlation between Chinese Visceral Adiposity Index and Nocturnal Hypertension in Young and Middle-aged People

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Abstract

Background: The Chinese visceral adiposity index (CVAI) is a novel obesity metric that has been proven to correlate closely with prehypertension and hypertension. However, research on the relationship between CVAI and nocturnal hypertension (NH) remains scarce. **Objective:** To investigate the association between CVAI and NH in young and middle-aged adults. **Methods:** A total of 981 young and middle-aged patients with essential hypertension admitted to the Department of Hypertension at the Fifth Affiliated Hospital of Xinjiang Medical University were consecutively enrolled from February 2023 to September 2023. General demographic data, biochemical indicators, and 24-hour ambulatory blood pressure monitoring (ABPM) results were collected, and CVAI was calculated. Patients were divided into a non-nocturnal hypertension (NNH) group (n=95) and an NH group (n=886) based on the presence or absence of NH. Inter-group differences in general characteristics, biochemical parameters, 24-hour ABPM results, and CVAI were compared. Pearson correlation analysis was used to explore the relationship between CVAI and NH. Multivariate logistic regression analysis was performed to identify influencing factors of NH in young and middle-aged adults. **Results:** The NH group exhibited significantly higher CVAI, 24-hour average systolic and diastolic blood pressure, daytime average systolic and diastolic blood pressure, nocturnal average systolic and diastolic blood pressure, and maximum systolic and diastolic blood pressure

compared with the NNH group (all P<0.05). Pearson correlation analysis revealed that CVAI was positively correlated with 24-hour average systolic and diastolic blood pressure, daytime average systolic and diastolic blood pressure, nocturnal average systolic and diastolic blood pressure, and maximum systolic and diastolic blood pressure (r=0.202, 0.183, 0.200, 0.171, 0.168, 0.174, 0.132, 0.157; all P<0.05). Multivariate logistic regression analysis showed that after adjusting for confounders such as sex and age, elevated CVAI was an independent risk factor for NH in young and middle-aged adults (OR=1.009, 95%CI=1.002-1.016, P=0.014). When patients were stratified by CVAI quartiles into Q1 (<103.5243, n=245), Q2 (103.5243-129.7140, n=246), Q3 (129.7140-156.2704, n=245), and Q4 (>156.2704, n=245) groups, the risks of NH in Q2, Q3, and Q4 groups were 1.779-fold (OR=1.779, 95%CI=1.002-3.157), 2.023-fold (OR=2.023, 95%CI=1.061-3.858), and 3.053-fold (OR=3.053, 95%CI=1.383-6.737) higher than in Q1, respectively. Subgroup analysis demonstrated that the association between CVAI and NH was more pronounced in overweight/obese individuals (BMI $\geq$ 24 kg/m^2) (P=0.021). **Conclusion:** CVAI is associated with the risk of NH in young and middle-aged adults, with a stronger association observed in overweight/obese populations (BMI $\geq$ 24 kg/m^2), suggesting that CVAI serves as a risk factor for NH in this population.

Keywords: Nocturnal hypertension; Chinese visceral adiposity index; Visceral obesity indicator; Young and middle-aged; Correlation study
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Introduction

Hypertension represents a major modifiable risk factor for cardiovascular disease and all-cause mortality worldwide. Nocturnal hypertension (NH) has garnered increasing clinical attention due to its close associations with asymptomatic target organ damage—including arterial stiffness, left ventricular hypertrophy, cerebral white matter lesions, and microalbuminuria—as well as its ability to independently predict cardiovascular and all-cause mortality beyond daytime blood pressure levels. Epidemiological surveys indicate a trend toward younger onset of hypertension, with young and middle-aged populations showing more pronounced increases in prevalence compared with older adults, alongside lower rates of awareness, treatment, and control. As 24-hour ambulatory blood pres-

sure monitoring (ABPM) remains the sole method for detecting nocturnal blood pressure abnormalities, yet is limited by screening awareness and accessibility, identifying simple and readily available indicators to recognize individuals at risk for NH is crucial for implementing preventive measures.

The Chinese visceral adiposity index (CVAI) has emerged as a novel obesity metric closely linked to visceral fat content and functional metabolism in Chinese populations, attracting considerable attention in cardiovascular research. Studies have demonstrated that visceral rather than subcutaneous or total adiposity correlates with elevated blood pressure. Traditional obesity indices such as body mass index (BMI) and waist circumference (WC) inadequately distinguish body fat content and distribution, particularly in assessing visceral adiposity. Building upon the visceral adiposity index (VAI), Xia et al. developed CVAI by incorporating BMI, age, high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG) levels, creating an accurate predictor of visceral fat content in Chinese populations consistent with imaging methods. Research has shown CVAI correlates with prehypertension, hypertension, coronary heart disease, and cardiometabolic multimorbidity. However, studies examining its relationship with NH remain limited. Therefore, this investigation aims to explore the association between CVAI and NH in young and middle-aged individuals to provide a scientific basis for early identification of high-risk individuals and development of targeted interventions.

Methods

1.1 Study Population

We enrolled 981 young and middle-aged patients with essential hypertension admitted to the Department of Hypertension at the Fifth Affiliated Hospital of Xinjiang Medical University between February 2023 and September 2023. According to NH diagnostic criteria—defined as nocturnal average systolic blood pressure $\geq$ 120 mmHg (1 mmHg = 0.133 kPa) and/or diastolic blood pressure $\geq$ 70 mmHg on ABPM—patients were divided into a non-nocturnal hypertension (NNH) group (n=95) and an NH group (n=886). Inclusion criteria were: (1) meeting diagnostic criteria for hypertension per the *Chinese Guidelines for the Prevention and Treatment of Hypertension (2024 Revision)*—office blood pressure $\geq$ 140/90 mmHg on three separate occasions without antihypertensive medication, or home blood pressure $\geq$ 135/85 mmHg over 5–7 consecutive days, or 24-hour ABPM $\geq$ 130/80 mmHg, daytime $\geq$ 135/85 mmHg, and nighttime $\geq$ 120/70 mmHg; patients with a history of hypertension currently on medication remained diagnosed regardless of values below these thresholds; (2) age 18–64 years per the *Chinese Expert Consensus on Hypertension Management in Young and Middle-aged Adults*; and (3) complete clinical data. Exclusion criteria comprised: (1) white-coat hypertension and secondary hypertension; (2) secondary obesity (e.g., Cushing' s syndrome, primary hypothyroidism) or medication-induced obesity; and (3) missing clinical indicators. This study was approved by the Ethics Committee of the Fifth Affiliated Hospital of Xinjiang

Medical University (Approval No.: XYDWFYLSk-2025-25).

1.2 Data Collection

1.2.1 General Data Collection We collected baseline demographics including age, sex, history of coronary heart disease, diabetes, smoking, and alcohol consumption. Height, weight, and WC were measured, and BMI was calculated. Coronary heart disease was defined as $ $50% stenosis in at least one coronary artery on angiography, or history of percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), or old myocardial infarction (OMI). Diabetes was defined as classic symptoms plus random glucose $\geq$ 11.1 mmol/L, fasting glucose $\geq$ 7.0 mmol/L, 2-hour oral glucose tolerance test $\geq$ 11.1 mmol/L, or history of diabetes with current use of hypoglycemic agents. Smoking was defined as $ $1 cigarette daily for $ $6 months; alcohol consumption as $ $3 times weekly with >50 g per occasion.

1.2.2 Ambulatory Blood Pressure Monitoring ABPM was performed using calibrated standard devices. Nocturnal measurements (23:00–08:00) were recorded hourly, and daytime measurements (08:00–23:00) every 20 minutes, ensuring $ $20 valid daytime readings, $ $7 valid nocturnal readings, and $ $70% of expected 24-hour readings. Daytime, nighttime, 24-hour, and maximum systolic and diastolic blood pressures were collected. NH was diagnosed when nocturnal average systolic blood pressure $\geq$ 120 mmHg and/or diastolic blood pressure $\geq$ 70 mmHg.

1.2.3 Laboratory Examinations After overnight fasting for $ $8 hours, venous blood samples were obtained to measure triglycerides (TG), total cholesterol (TC), HDL-C, low-density lipoprotein cholesterol (LDL-C), blood urea nitrogen (BUN), serum creatinine (SCr), red blood cell count, and hemoglobin.

1.2.4 CVAI Calculation CVAI was calculated using the following formulas:
Males: CVAI = -267.93 + 0.68 × age (years) + 0.03 × BMI (kg/m^2) + 4.00 × WC (cm) + 22.00 × $\log_{10}$TG (mmol/L) - 16.32 × HDL-C (mmol/L)
Females: CVAI = -187.32 + 1.71 × age (years) + 4.23 × BMI (kg/m^2) + 1.12 × WC (cm) + 39.76 × $\log_{10}$TG (mmol/L) - 11.66 × HDL-C (mmol/L)

1.3 Statistical Analysis

Data were analyzed using SPSS 27.0. Normally distributed continuous variables are presented as mean ± standard deviation and compared using independent samples t-tests. Non-normally distributed continuous variables are expressed as median (P_{25}, P_{75}) and compared using Mann-Whitney U tests. Categorical data are presented as percentages and compared using ^{2} tests. Pearson or Spearman correlation analyses examined associations between CVAI and other variables. Multivariate logistic regression analysis identified influencing factors of NH in young and middle-aged adults. Statistical significance was set at $P<0.05$.

Results

2.1 Comparison of General Characteristics Between Groups

This study included 981 young and middle-aged hypertensive patients (627 males [63.9%], 354 females [36.1%]) with a mean age of 50.5 ± 9.4 years and mean CVAI of 131.14 ± 41.75. The NH group (n=886) showed significantly higher proportions of males, smoking history, alcohol consumption, BMI, WC, TG, CVAI, SCr, 24-hour average systolic and diastolic blood pressure, daytime average systolic and diastolic blood pressure, nocturnal average systolic and diastolic blood pressure, maximum systolic and diastolic blood pressure, and hemoglobin, but lower age compared with the NNH group (n=95) (all $P<0.05$). No significant differences were observed in HDL-C, TC, LDL-C, BUN, history of coronary heart disease, or diabetes between groups (all $P>0.05$) .

2.2 Correlation Analysis Between CVAI and Variables

Pearson correlation analysis revealed that CVAI was positively correlated with 24-hour average systolic and diastolic blood pressure, daytime average systolic and diastolic blood pressure, nocturnal average systolic and diastolic blood pressure, maximum systolic and diastolic blood pressure, BMI, and WC (r=0.202, 0.183, 0.200, 0.171, 0.168, 0.174, 0.132, 0.157, 0.760, 0.922; all $P<0.05$), and negatively correlated with age (r=-0.067, $P<0.05$). Spearman correlation analysis showed that CVAI was positively correlated with smoking, alcohol consumption, TG, BUN, SCr, red blood cell count, hemoglobin, and diabetes (rs=0.307, 0.313, 0.331, 0.116, 0.309, 0.285, 0.387, 0.094; all $P<0.05$), and negatively correlated with sex and HDL-C (rs=-0.490, -0.396; all $P<0.05$) .

2.3 Multivariate Logistic Regression Analysis of NH Influencing Factors

Using NH status (no=0, yes=1) as the dependent variable and CVAI (continuous) as the independent variable, multivariate logistic regression analysis adjusted for confounders including sex (male=1, female=2), smoking history (no=0, yes=1), alcohol history (no=0, yes=1), age, TG, SCr, red blood cell count, and hemoglobin revealed that elevated CVAI was an independent risk factor for NH in young and middle-aged adults (OR=1.009, 95%CI=1.002-1.016, P=0.014). When CVAI was analyzed as a categorical variable based on quartiles—Q1 (<103.5243, n=245), Q2 (103.5243-129.7140, n=246), Q3 (129.7140-156.2704, n=245), and Q4 (>156.2704, n=245)—with Q1 as reference, the risks of NH in Q2, Q3, and Q4 groups were 1.779-fold (OR=1.779, 95%CI=1.002-3.157), 2.023-fold (OR=2.023, 95%CI=1.061-3.858), and 3.053-fold (OR=3.053, 95%CI=1.383-6.737) higher, respectively .

2.4 Subgroup Analysis of NH Influencing Factors

Stratified by sex, further multivariate logistic regression analysis showed no significant association between CVAI and NH in either male (OR=1.008,

95%CI=0.999-1.016, P=0.084) or female subgroups (OR=1.011, 95%CI=0.999-1.024, P=0.068). However, when stratified by BMI into <24 kg/m^2 and $ 24kg/m^{2}$ subgroups, CVAI was significantly associated with NH in the BMI $ 24kg/m^{2}$ subgroup (OR=1.012, 95%CI=1.002-1.021, P=0.021) .

Discussion

Nocturnal hypertension constitutes a risk factor for target organ damage involving the heart, brain, kidneys, and vasculature, as well as for cardiovascular events, independent of office blood pressure levels. Therefore, early diagnosis and intervention for NH are critical for reducing cardiovascular risk. This study represents the first systematic analysis of the association between CVAI and NH in young and middle-aged populations. Our findings demonstrate that after adjusting for relevant confounders, elevated CVAI level is a risk factor for NH incidence (OR=1.009, 95%CI=1.002-1.016, P=0.014). When analyzed categorically, Q2, Q3, and Q4 groups showed 1.779-fold, 2.023-fold, and 3.053-fold higher risks of NH compared with Q1, respectively. These results suggest that visceral fat accumulation may be a driving factor underlying nocturnal blood pressure abnormalities in young and middle-aged individuals. Subgroup analysis further indicates that this association is more pronounced in overweight/obese populations (BMI $ 24kg/m^{2}$).

Research indicates that NH prevalence is notably high among young and middle-aged hypertensive patients in China, a finding consistent with our study where NH prevalence reached 90.3%. A cohort study of 59,124 participants followed for 9.7 years demonstrated that nocturnal systolic blood pressure remained closely associated with all-cause and cardiovascular mortality even after adjusting for daytime systolic pressure. Similarly, Boggia et al. reported that nocturnal blood pressure was a significant predictor of total, cardiovascular, and non-cardiovascular mortality after adjusting for confounders. A Japanese study found that nocturnal systolic blood pressure was significantly associated with atherosclerotic cardiovascular disease (ASCVD) and heart failure risk in individuals with at least one cardiovascular risk factor. Research in elderly populations showed that cognitive impairment was associated with elevated nocturnal systolic blood pressure. Presta et al. identified NH as an independent risk factor for stroke. Additionally, NH patients exhibited significantly increased pulse wave velocity (PWV), carotid intima-media thickness, and left ventricular mass index (LVMI) compared with those with normal nocturnal blood pressure. A cross-sectional study demonstrated that NH was significantly associated with left ventricular hypertrophy (OR=11.1, 95%CI=3.0-40.1), whereas non-dipping hypertension was not (OR=1.4, 95%CI=0.4-5.5). Another cross-sectional study of 2,386 non-dialysis chronic kidney disease (CKD) patients revealed that combined morning and nocturnal hypertension conferred higher risks of left ventricular hypertrophy (OR=2.87, 95%CI=2.01-4.09), increased carotid intima-media thickness (OR=2.01, 95%CI=1.47-2.75), reduced glomerular filtration rate (OR=3.18, 95%CI=2.23-4.54), and proteinuria (OR=1.79, 95%CI=1.33-

2.40) compared with those without morning or nocturnal hypertension, with high cardiovascular and renal risks also observed in the isolated nocturnal hypertension group. Collectively, these findings underscore the close relationship between NH and both cardiovascular disease and hypertensive target organ damage, highlighting the importance of nocturnal blood pressure control in reducing these risks. Our study demonstrates a positive correlation between CVAI level and NH risk, particularly pronounced in individuals with BMI $ $24kg/m^{2}$$, suggesting that CVAI may serve as a simple and reliable indicator for identifying high-risk populations.

Overweight and obesity are established risk factors for hypertension, with regional fat distribution proving more important than total body fat. Excess visceral fat has been confirmed to correlate with hypertension. CVAI has become a direct and reliable indicator for evaluating visceral adiposity in Chinese individuals. Gui et al. conducted a cross-sectional study of 9,488 middle-aged and elderly individuals over 45 years, demonstrating that CVAI was more closely associated with hypertension than 13 other obesity-related indices, with each unit increase in CVAI raising hypertension risk by 1.01-fold. Another study of 3,884 individuals aged $ $60 years similarly showed higher CVAI levels in hypertensive versus non-hypertensive populations, with the highest CVAI quartiles showing increased hypertension risk. Subgroup analyses aged individuals with $BMI > 23.6 kg/m^{2}$$ are more prone to blood pressure abnormalities, and our findings reveal that young and middle-aged hypertensive patients with BMI $ $24kg/m^{2}$$ are more susceptible to NH. Using ABPM as the diagnostic standard for NH avoids the white-coat effect of office measurements and biases of home self-monitoring. Our focus on young and middle-aged populations clarifies the relationship between visceral fat and nocturnal blood pressure in this specific group.

Potential mechanisms linking visceral fat to hypertension include: (1) secretion of adipocytokines involved in blood pressure elevation; (2) production of free fatty acids via the portal vein leading to insulin resistance, which is implicated in hypertension pathogenesis; (3) higher cardiac sympathetic activity in visceral versus subcutaneous obesity; (4) activation of the renin-angiotensin-aldosterone system, which is associated with obesity-related hypertension, with increased venous return during supine position at night potentially elevating nocturnal blood pressure; and (5) abdominal obesity as a risk factor for obstructive sleep apnea syndrome (OSAS), where visceral fat plays a crucial role and nocturnal hypoxemia triggers sympathetic activation, resulting in elevated nocturnal blood pressure.

This study has several limitations. First, its cross-sectional design precludes establishing causality between CVAI and NH. Second, although we adjusted for some confounders, factors such as sleep quality and OSAS history were not accounted for. Third, the study was limited to young and middle-aged populations, potentially limiting generalizability to other age groups. Finally, the substantial disparity in sample sizes between groups may affect statistical

stability.

In conclusion, CVAI correlates with NH risk in young and middle-aged adults, with a more significant association in overweight/obese populations (BMI \$ $24kg/m^{2}$\$). Therefore, for young and middle-aged hypertensive patients, particularly those with BMI \$ $24kg/m^{2}$\$, body composition analysis should be performed to assess visceral fat levels, enabling targeted interventions to reduce visceral adiposity and ultimately decrease the risk of NH and its complications.

Author Contributions: ZHANG Qiuyu conceived and designed the study, conducted the research, wrote the manuscript, and takes responsibility for the article; ZHANG Qiuyu and HU Xiaoyong collected and organized data and performed statistical analysis; TANG Rui revised the manuscript; LI Hongjian supervised quality control and review. The authors declare no conflicts of interest.

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Note: Figure translations are in progress. See original paper for figures.