

Original Article

Association between visceral adiposity index and hypertension in reproductive-aged women: evidence from NHANES 1999-2023

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Abstract: Objectives: The visceral adiposity index (VAI), an indicator of visceral fat accumulation and dysfunction, has been proposed as a potential marker for cardiometabolic risk. However, its association with hypertension in women of reproductive age remains unclear. Therefore, this study aims to investigate the association between VAI and the prevalence of hypertension in this specific population. Methods: This cross-sectional study analyzed data from 2,571 women of reproductive age using the National Health and Nutrition Examination Survey (NHANES) database. Weighted multivariable logistic regression models were used to examine the relationship between VAI and hypertension, adjusting for potential confounders. Restricted cubic spline (RCS) modeling and two-piecewise linear regression were applied to evaluate the dose-response and threshold effects. Subgroup and interaction analyses were conducted across demographic and lifestyle factors. Results: VAI was significantly and positively associated with the prevalence of hypertension in women of reproductive age (OR = 1.18, 95% CI: 1.08-1.29; $P < 0.001$). Smooth curve fitting revealed a nonlinear positive relationship (nonlinear $P < 0.001$), with a notable inflection point at VAI = 1.285. Below this threshold, the odds of hypertension increased sharply (OR = 4.48; 95% CI: 2.25-8.91; $P < 0.001$), while above it, the odds increased modestly (OR = 1.07; 95% CI: 1.02-1.13; $P = 0.008$). Subgroup analyses confirmed the robustness of this association across most strata. A significant interaction was found in the racial/ethnic subgroup (P for interaction = 0.017), suggesting varying strength of association among different racial groups. Conclusion: VAI is independently and nonlinearly associated with increased odds of hypertension in women of reproductive age, demonstrating a distinct threshold effect. These findings suggest that VAI may serve as a potential observational marker for evaluating cardiovascular risk in this population. Maintaining VAI below the 1.285 threshold could be considered in early cardiovascular prevention strategies.

Keywords: Visceral adiposity index, reproductive-age women, hypertension, NHANES, cross-sectional study, association

Introduction

Hypertension is a major public health concern and a leading cause of morbidity and mortality worldwide. It is well established as a key risk factor for cardiovascular disease [1, 2], chronic kidney disease [3], stroke [4], and vascular dementia [5]. In the United States, the prevalence of hypertension among adults aged 18 years and older was estimated at 45.4% in 2017-2018 [6].

Although its overall prevalence is lower in women (39.7%) compared to men (51.0%), hypertension remains a significant public health issue for female populations, particularly among those of reproductive age. This group is often disproportionately affected by psychosocial factors such as stress and anxiety, which may exacerbate blood pressure levels [7]. Moreover, chronic hypertension in women is associated with adverse pregnancy outcomes, including an increased risk of preeclampsia,

which threatens both maternal and fetal health [8, 9]. Maintaining healthy blood pressure before and during pregnancy is critical to reducing the risks of complications such as miscarriage, preterm birth, low birth weight, and future metabolic disorders in offspring [10, 11]. Among women aged 20 to 45 years, approximately 19% are affected by hypertension, and the prevalence increases with age. However, because many first-line antihypertensive medications are contraindicated during pregnancy, managing blood pressure in clinical settings becomes highly challenging once a woman conceives [12]. Given that nearly 40% of maternal deaths are associated with hypertensive disorders, there is an urgent need for early prediction and preventive strategies in reproductive-aged women to optimize their baseline cardiovascular health before pregnancy [13].

Multiple modifiable risk factors contribute to hypertension, including high sodium and low potassium intake, tobacco and alcohol use, psychological stress, sleep disorders, and most notably, overweight and obesity [14]. Obesity is a well-recognized driver of hypertension, affecting roughly 70% of obese individuals [15]. Although traditional anthropometric indices such as body mass index (BMI) [16], waist circumference (WC) [17], and hip circumference are widely used to evaluate obesity, they lack precision in assessing visceral adiposity and adipose tissue dysfunction [18].

To address these limitations, the visceral adiposity index (VAI) has been proposed as a more accurate indicator of visceral fat distribution and cardiometabolic risk [19]. VAI correlates with visceral fat area and volume independently of subcutaneous fat and has been introduced as a surrogate marker of adipose tissue dysfunction. It has been linked to various metabolic and cardiovascular conditions, including insulin resistance [20], kidney stones [21], heart failure [22], and depression [23]. Epidemiological studies have demonstrated a positive association between VAI and hypertension in specific populations, such as Chinese adults, and have identified a nonlinear relationship with cardiovascular diseases [24]. However, evidence on sex differences remains inconsistent, and large-scale studies in U.S. populations are scarce.

Importantly, although elevated VAI levels have been observed in individuals with poor blood

pressure control, the association between VAI and hypertension specifically among reproductive-aged women has not been well studied. This population is of particular interest due to the dual burden of long-term cardiovascular risk and future pregnancy-related complications. Therefore, the present study aims to investigate the association between VAI and hypertension among reproductive-aged women in the United States using data from eleven cycles of the National Health and Nutrition Examination Survey (NHANES) spanning 1999 to 2023. Our findings may provide novel insights into early screening and risk stratification for hypertension in this vulnerable population, offering scientific evidence to inform targeted prevention and clinical intervention strategies.

Methods

Study population

The National Health and Nutrition Examination Survey (NHANES) is a series of cross-sectional surveys designed to assess the health and nutritional status of the civilian, non-institutionalized U.S. population. Publicly available data from eleven consecutive survey cycles (1999-2023) were downloaded from the NHANES website (<https://www.cdc.gov/nchs/nhanes/index.htm>). All participants provided written informed consent, and the protocols were approved by the National Center for Health Statistics (NCHS) Ethics Review Board [25]. To establish the study cohort, specific inclusion and exclusion criteria were applied. The inclusion criteria were: (1) female participants; and (2) reproductive age, defined as 20 to 45 years. The exclusion criteria were: (1) participants missing one or more components necessary to calculate the Visceral Adiposity Index (VAI); (2) participants with missing hypertension status; and (3) individuals with incomplete covariate data. After applying these criteria (**Figure 1**), the final analytic sample consisted of 2,571 women aged 20-45 years with complete data on VAI, blood pressure, and covariates.

Definition of visceral adiposity index (VAI)

Fasting blood samples were collected and analyzed according to standardized CDC protocols. Trained personnel measured anthropometric indices and processed laboratory as-

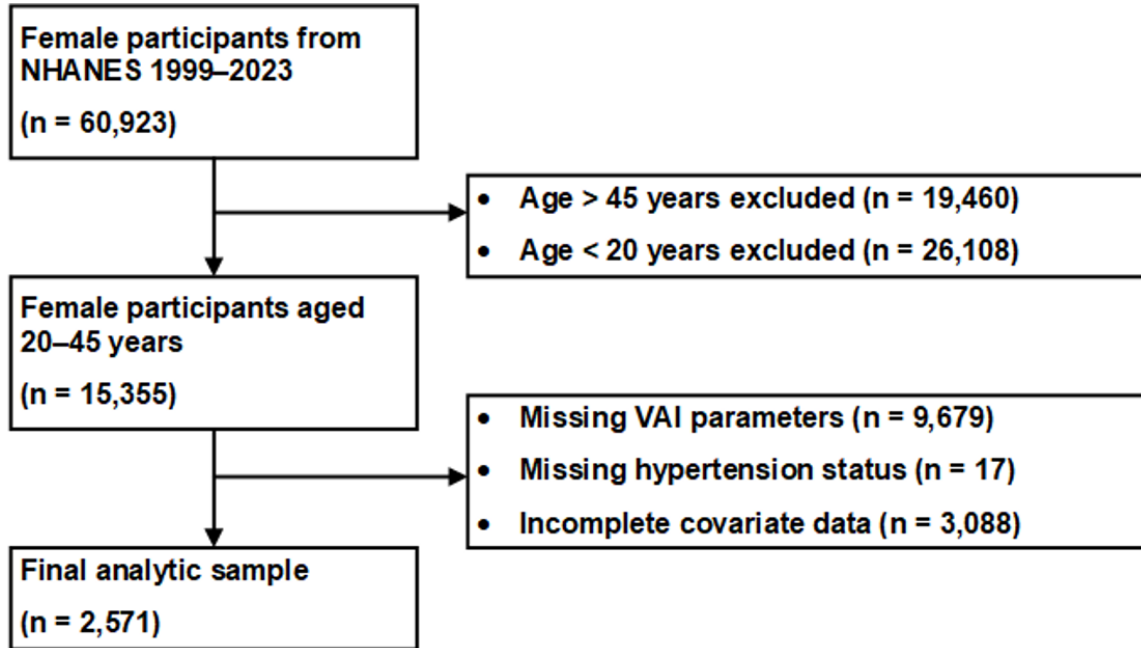


Figure 1. Flowchart of participant selection from the NHANES 1999-2023.

says. The VAI integrates anthropometric parameters - body mass index (BMI; kg/m²) and waist circumference (WC; cm) - with lipid biomarkers - triglycerides (TG; mmol/L) and high-density lipoprotein cholesterol (HDL-C; mmol/L) [19, 26]. For women, VAI was calculated as follows:

$$VAI = \frac{WC}{36.58 + 1.89 \times BMI} \times \frac{TG}{0.81} \times \frac{1.52}{HDL - C}$$

Definition of hypertension

Certified examiners measured blood pressure (BP) using mercury sphygmomanometers according to American Heart Association guidelines [27]. After a 5-minute seated rest, three consecutive readings were taken at intervals of at least 1 minute, and the mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) were calculated. Hypertension was defined by any of the following criteria: (i) self-reported physician diagnosis of hypertension; (ii) current use of antihypertensive medications; or (iii) mean SBP ≥ 140 mmHg and/or mean DBP ≥ 90 mmHg.

Covariates

Potential confounders were selected based on prior literature [28, 29] and included demo-

graphic, socioeconomic, lifestyle, anthropometric, laboratory, and medical history variables: (1) Age groups: 20-34 years and 35-45 years; (2) Race/Ethnicity: Mexican American; non-Hispanic White; non-Hispanic Black; other Hispanic; other race; (3) Education: < 9th grade; 9-11th grade; high school graduate; some college; college graduate or above; (4) Marital Status: married; widowed; divorced; separated; never married; cohabitating; (5) Family Poverty-Income Ratio (PIR): < 1.3; 1.3-3.5; ≥ 3.5; (6) Smoking status: ever smoker vs. never smoker; (7) Alcohol consumption (past 12 months): light (≤ 1 drink/day), moderate (1-3 drinks/day), heavy (≥ 4 drinks/day) [30]; (8) Body Mass Index (BMI, kg/m²); (9) Physical activity: based on a 30-day recall questionnaire recording type, duration, intensity, and frequency; categorized as low (< 500 MET-min/week) or high (≥ 500 MET-min/week) [31]; (10) Laboratory measures: total cholesterol (TC), HDL-C, triglycerides (TG); (11) Diabetes mellitus (DM): self-reported diagnosis or current use of antidiabetic medications.

Additionally, baseline characteristics such as Body Mass Index (BMI, kg/m²), total cholesterol (TC), HDL-C, and triglycerides (TG) were described. Components used to calculate VAI (BMI, WC, TG, and HDL-C) and TC were not

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Table 1. Baseline characteristics of reproductive-aged women stratified by hypertension status

Variable	Total (n = 2571)	Non-hypertension (n = 2159)	Hypertension (n = 412)	Statistic	P
Age, n (%)				$\chi^2 = 103.44$	< 0.001
20-34	1546 (58.82)	1389 (62.97)	157 (35.36)		
35-45	1025 (41.18)	770 (37.03)	255 (64.64)		
Race, n (%)				$\chi^2 = 27.94$	< 0.001
Mexican American	357 (8.15)	317 (8.38)	40 (6.84)		
Non-Hispanic White	229 (5.96)	200 (6.20)	29 (4.57)		
Non-Hispanic Black	1142 (66.42)	979 (67.31)	163 (61.39)		
Other Hispanic	555 (11.98)	411 (10.58)	144 (19.88)		
Other Race	288 (7.49)	252 (7.52)	36 (7.32)		
Education, n (%)				$\chi^2 = 28.61$	< 0.001
Less than 9th grade	73 (1.92)	60 (1.61)	13 (3.67)		
9-11th grade	253 (7.17)	203 (6.66)	50 (10.10)		
High school graduate	443 (16.11)	369 (16.17)	74 (15.80)		
Some college	999 (37.83)	816 (36.85)	183 (43.39)		
College graduate or above	803 (36.96)	711 (38.72)	92 (27.04)		
Marital status, n (%)				$\chi^2 = 22.78$	0.006
Married	1170 (50.06)	993 (50.06)	177 (50.08)		
Widowed	70 (2.33)	53 (1.92)	17 (4.62)		
Divorced	355 (14.26)	276 (13.61)	79 (17.93)		
Separated	71 (1.83)	59 (1.87)	12 (1.64)		
Never married	644 (22.06)	563 (23.16)	81 (15.82)		
Cohabiting	261 (9.45)	215 (9.37)	46 (9.91)		
PIR, n (%)				$\chi^2 = 5.22$	0.166
< 1.3	797 (22.23)	651 (21.76)	146 (24.88)		
1.3-3.5	967 (37.28)	807 (36.83)	160 (39.79)		
≥ 3.5	807 (40.50)	701 (41.41)	106 (35.33)		
Smoking History, n (%)				$\chi^2 = 31.56$	< 0.001
Never	1635 (62.16)	1418 (64.42)	217 (49.39)		
Ever	936 (37.84)	741 (35.58)	195 (50.61)		
Alcohol Consumption (past 12 months), n (%)				$\chi^2 = 1.33$	0.617
Light	854 (32.25)	718 (31.83)	136 (34.61)		
Moderate	1246 (50.12)	1053 (50.56)	193 (47.67)		
Heavy	471 (17.62)	388 (17.61)	83 (17.72)		
Physical Activity, n (%)				$\chi^2 = 8.31$	0.010
Low	818 (28.88)	674 (27.80)	144 (35.00)		
High	1753 (71.12)	1485 (72.20)	268 (65.00)		
DM, n (%)				$\chi^2 = 109.63$	< 0.001
No	2415 (94.65)	2066 (96.60)	349 (83.61)		
Yes	156 (5.35)	93 (3.40)	63 (16.39)		
TC, mmol/L, Mean (SE)	4.75 (0.02)	4.73 (0.03)	4.86 (0.06)	t = 2.17	0.032
TG, mmol/L, Mean (SE)	1.13 (0.02)	1.07 (0.02)	1.49 (0.07)	t = 6.21	< 0.001
HDL, mmol/L, Mean (SE)	1.51 (0.01)	1.54 (0.01)	1.38 (0.03)	t = -5.46	< 0.001
BMI, kg/m ² , Mean (SE)	28.71 (0.18)	27.78 (0.20)	34.01 (0.49)	t = 11.27	< 0.001
VAI, Mean (SE)	1.71 (0.05)	1.56 (0.04)	2.56 (0.17)	t = 5.94	< 0.001

Data are mean ± SE or n (%) for categorical variables. Abbreviations: SE, standard error; BMI, body mass index; TC, total cholesterol; TG, triglycerides; HDL, high-density lipoprotein; DM, diabetes mellitus; PIR, poverty-income ratio.

included as covariates in the multivariable adjustment models. The remaining covariates were included in multivariable models to adjust for potential confounding.

Statistical analysis

Statistical analyses were performed using R version 4.3.1. Given the complex sampling de-

sign of NHANES, appropriate sample weights, primary sampling units (PSUs), and strata were incorporated into all relevant analyses to produce nationally representative estimates. Continuous variables are presented as means \pm standard errors (SE) and compared using weighted Student's t-tests. Categorical variables are presented as frequencies (percentages) and compared using weighted chi-square tests. VAI was categorized into quartiles.

Weighted multivariable logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the association between VAI quartiles and hypertension. Three sequential models were constructed: Model 1: unadjusted; Model 2: adjusted for race/ethnicity, education, marital status, and age group; Model 3: further adjusted for smoking status, alcohol consumption, PIR, physical activity level, and diabetes status.

Restricted cubic spline (RCS) functions with three knots were employed to assess potential nonlinear associations. To further quantify the threshold effect, a two-piecewise linear regression model was applied. The exact inflection point was determined, and a log-likelihood ratio test was conducted to compare the one-line linear model with the two-piecewise model. Subgroup analyses stratified by age, race/ethnicity, education, marital status, smoking, alcohol use, and diabetes were performed by including interaction terms. Statistical significance was defined as two-sided $P < 0.05$.

Results

Baseline characteristics

A total of 2,571 women aged 20-45 years were included from the NHANES database, comprising 2,159 non-hypertensive and 412 hypertensive participants (**Figure 1**). Weighted baseline characteristics stratified by hypertension status are presented in **Table 1**. Compared with participants without hypertension, those with hypertension were significantly older (≥ 35 years: 64.64% vs. 37.03%, $P < 0.001$) and had higher body mass index (BMI: 34.01 vs. 27.78 kg/m², $P < 0.001$). The hypertensive group also demonstrated a more adverse lipid profile, with significantly higher triglyceride levels (1.49 vs. 1.07 mmol/L, $P < 0.001$), lower high-density lipoprotein cholesterol (HDL-C: 1.38

vs. 1.54 mmol/L, $P < 0.001$), and slightly elevated total cholesterol (4.86 vs. 4.73 mmol/L, $P = 0.032$). The prevalence of diabetes was markedly higher among hypertensive participants (16.39% vs. 3.40%, $P < 0.001$), as was the proportion with a history of smoking (50.61% vs. 35.58%, $P < 0.001$) and low physical activity levels (35.00% vs. 27.80%, $P = 0.010$). Notably, the mean visceral adiposity index (VAI) was significantly elevated in the hypertension group (2.56 vs. 1.56, $P < 0.001$). Significant differences were also observed in educational attainment ($P < 0.001$), with fewer individuals with hypertension having completed college or higher education (27.04% vs. 38.72%). Moreover, race/ethnicity distributions differed significantly between groups ($P < 0.001$), with a higher proportion of "Other Hispanic" individuals among hypertensive participants (19.88% vs. 10.58%). Marital status was also significantly associated with hypertension status ($P = 0.006$); for example, widowed and divorced individuals were more prevalent among those with hypertension. In contrast, no significant differences were detected in poverty-income ratio (PIR) ($P = 0.166$) or alcohol consumption patterns ($P = 0.617$) between the two groups.

Association between visceral adiposity index and hypertension in women of reproductive age

As shown in **Table 2**, the Visceral Adiposity Index (VAI) was positively associated with the prevalence of hypertension among women of reproductive age. In the unadjusted model (Model 1), participants in higher VAI quartiles had significantly increased odds of hypertension compared to those in the lowest quartile (Q1, VAI ≤ 0.76). The odds ratios (ORs) and 95% confidence intervals (CIs) were 1.69 (1.09-2.60) for Q2, 2.44 (1.67-3.56) for Q3, and 4.45 (3.06-6.47) for Q4 (P for trend < 0.001). After adjustment for race/ethnicity, education level, marital status, and age category in Model 2, the association remained significant. The ORs (95% CIs) for hypertension across VAI quartiles were 1.69 (1.08-2.64) in Q2, 2.55 (1.73-3.76) in Q3, and 4.50 (3.04-6.68) in Q4 (P for trend < 0.001). Further adjustment for smoking history, alcohol consumption, poverty-income ratio (PIR), physical activity level, and diabetes status in Model 3 did not weaken the

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Table 2. Association between VAI and hypertension in women of reproductive age

Variables	Model1		Model2		Model3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
VAI group						
Q1 (VAI ≤ 0.76)	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Q2 (0.76 < VAI ≤ 1.23)	1.69 (1.09-2.60)	0.020	1.69 (1.08-2.64)	0.023	1.63 (1.05-2.53)	0.032
Q3 (1.23 < VAI ≤ 1.98)	2.44 (1.67-3.56)	< 0.001	2.55 (1.73-3.76)	< 0.001	2.36 (1.61-3.48)	< 0.001
Q4 (VAI > 1.98)	4.45 (3.06-6.47)	< 0.001	4.50 (3.04-6.68)	< 0.001	3.55 (2.39-5.27)	< 0.001
P for trend	< 0.001		< 0.001		< 0.001	

Abbreviations: OR, Odds Ratio; CI, Confidence Interval. Model 1: Unadjusted; Model 2: Adjusted for race/ethnicity, education level, marital status, and age category; Model 3: Further adjusted for smoking history, alcohol consumption, PIR, physical activity level, and diabetes status.

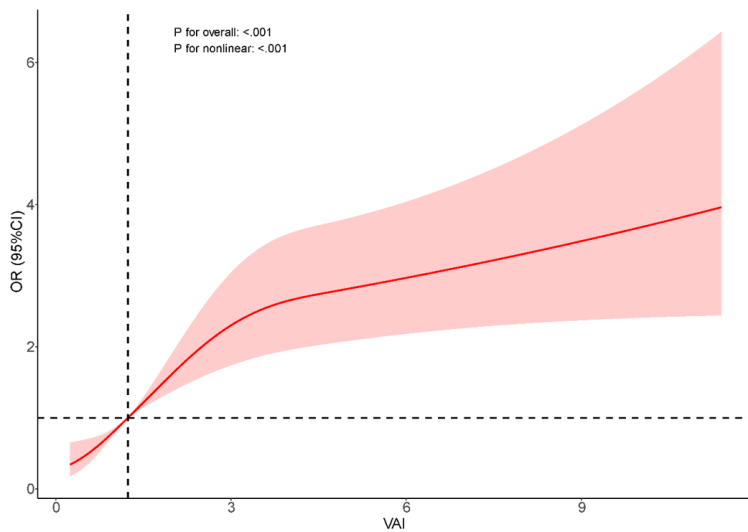


Figure 2. Association between visceral adiposity index and hypertension in women of reproductive age.

Table 3. Two-piecewise logistic regression analysis of the association between VAI and hypertension

Outcome	OR (95% CI)	P
Model 1: Standard linear regression	1.14 (1.08-1.21)	< 0.001
Model 2: Two-piecewise linear regression		
Inflection point	1.285	
< 1.285	4.48 (2.25-8.91)	< 0.001
≥ 1.285	1.07 (1.02-1.13)	0.008
P for likelihood test		< 0.001

association. The ORs (95% CIs) were 1.63 (1.05-2.53) for Q2, 2.36 (1.61-3.48) for Q3, and 3.55 (2.39-5.27) for Q4 (P for trend < 0.001). These findings indicate a robust and independent positive association between increasing VAI and the odds of hypertension in this population, with a clear dose-response

relationship across VAI quartiles.

Curve fitting and threshold effect analysis

Smooth curve fitting using restricted cubic splines (RCS) was performed to explore the relationship between the Visceral Adiposity Index (VAI) and hypertension prevalence. After adjusting for age, race/ethnicity, education level, marital status, poverty-income ratio (PIR), smoking history, alcohol consumption, and diabetes mellitus (DM), a significant non-linear association was observed (P for nonlinearity < 0.001; **Figure 2**). Specifically, the probability of hypertension increased in a nonlinear and positively increasing manner as VAI rose, with a steeper increase below the threshold and a more gradual increase above the threshold. To further quantify and validate this non-linear association, a two-piecewise linear regression (threshold effect) analysis was conducted using the segmented

package in R (**Table 3**). The overall association between VAI and hypertension remained significantly positive, with an odds ratio (OR) of 1.14 (95% confidence interval [CI]: 1.08-1.21; P < 0.001). A turning point was identified at VAI = 1.285 (P value for likelihood ratio test < 0.001). Below this threshold (VAI < 1.285), each 1-unit

increase in VAI was associated with a substantially elevated odds of hypertension (OR = 4.48; 95% CI: 2.25-8.91; $P < 0.001$). Above the threshold (VAI ≥ 1.285), the positive association persisted but with a reduced effect size (OR = 1.07; 95% CI: 1.02-1.13; $P = 0.008$). These findings suggest a significant nonlinear and threshold-dependent relationship between VAI and the odds of hypertension in women of reproductive age.

Subgroup and interaction analyses

To evaluate the robustness of the association between VAI and hypertension, subgroup analyses were conducted based on demographic and lifestyle factors (**Table 4**). In the fully adjusted model, the positive association between VAI and hypertension was consistent across most subgroups, including education, marital status, smoking history, alcohol consumption, physical activity, diabetes status, age, and poverty-income ratio (PIR), with no significant interactions detected (all P for interaction > 0.05). However, a significant interaction was observed in the racial/ethnic subgroup (P for interaction = 0.017), indicating that the strength of the association between VAI and hypertension varied significantly among different racial/ethnic groups. Nevertheless, the overall trend remained positive, supporting the conclusion that higher VAI is an independent correlate for prevalent hypertension in women of reproductive age.

Discussion

In this large, nationally representative sample of U.S. women of reproductive age, we examined the association between visceral adiposity index (VAI) and hypertension using data from eleven NHANES cycles (1999-2023). After applying stringent inclusion and exclusion criteria, a final analytical sample of 2,571 women aged 20-45 years was selected. Participants were stratified by hypertension status, and weighted analyses were conducted to assess baseline characteristics. We employed multivariable logistic regression to evaluate the independent association between VAI and hypertension, while restricted cubic spline (RCS) modeling and two-piecewise linear regression were used to explore potential non-linearity and threshold effects. Furthermore, stratified subgroup analyses and interaction

testing were performed to assess the robustness of our findings across various demographic and clinical subpopulations.

The relationship between visceral adiposity and hypertension has been well established in the general adult population [28], but few studies have specifically focused on women of reproductive age. VAI, which integrates both anthropometric (BMI and waist circumference) and metabolic (triglycerides and HDL-C) parameters, has emerged as a surrogate marker of visceral fat dysfunction and cardiometabolic risk [19, 32]. Visceral adiposity may promote the development of hypertension via several interrelated mechanisms, including chronic low-grade inflammation, activation of the renin-angiotensin-aldosterone system (RAAS), sympathetic nervous system overactivity, insulin resistance, and impaired endothelial function [24, 33, 34].

Although some studies have demonstrated a positive association between VAI and elevated blood pressure or cardiovascular risk in middle-aged and elderly individuals [24, 35, 36], limited data are available in younger female populations, who may have unique hormonal and metabolic characteristics. Our study contributes to this gap by demonstrating a strong, independent, and nonlinear association between higher VAI and increased odds of prevalent of hypertension in women aged 20-45 years, with a threshold effect identified at a VAI of 1.285.

Our study has several strengths. First, we used nationally representative data from NHANES with standardized protocols, enhancing the generalizability of our findings. Second, we applied complex survey weighting and multiple analytical approaches, including nonlinear modeling and interaction testing, to ensure methodological robustness. Third, our focus on reproductive-aged women addresses an understudied population that is critical for early prevention of cardiovascular disease.

However, some limitations should be noted. First, the cross-sectional design limits our ability to infer causality between VAI and hypertension. Because our study evaluates the overall prevalence rather than the incidence of hypertension, we deliberately did not exclude patients with a prior diagnosis of hypertension; doing so would artificially deflate the true dis-

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Table 4. Subgroup analyses for the association between VAI and hypertension in women of reproductive age

Variables	n (%)	OR (95% CI)	P	P for interaction
All patients	2571 (100.00)	1.18 (1.08-1.29)	< 0.001	
Age				0.138
< 35	1546 (60.13)	1.12 (1.02-1.23)	0.021	
≥ 35	1025 (39.87)	1.27 (1.16-1.39)	< 0.001	
Race				0.017
Mexican American	357 (13.89)	0.99 (0.92-1.07)	0.843	
Non-Hispanic White	229 (8.91)	1.39 (1.04-1.85)	0.045	
Non-Hispanic Black	1142 (44.42)	1.22 (1.08-1.38)	0.002	
Other Hispanic	555 (21.59)	1.23 (0.95-1.58)	0.126	
Other Race	288 (11.20)	1.52 (1.12-2.05)	0.012	
Education				0.211
Less than 9th grade	73 (2.84)	1.21 (0.78-1.88)	0.394	
9-11th grade	253 (9.84)	1.01 (0.93-1.10)	0.795	
High school graduate	443 (17.23)	1.24 (0.98-1.58)	0.080	
Some college	999 (38.86)	1.18 (1.03-1.35)	0.021	
College graduate or above	803 (31.23)	1.29 (1.05-1.59)	0.018	
Marital status				0.217
Married	1170 (45.51)	1.10 (0.97-1.24)	0.153	
Widowed	70 (2.72)	2.99 (0.99-9.06)	0.052	
Divorced	355 (13.81)	1.58 (1.25-1.99)	< 0.001	
Separated	71 (2.76)	2.06 (0.20-21.46)	0.542	
Never married	644 (25.05)	1.18 (1.01-1.39)	0.042	
Cohabiting	261 (10.15)	1.15 (0.98-1.36)	0.103	
PIR				0.441
< 1.3	797 (31.00)	1.19 (1.07-1.33)	0.002	
1.3-3.5	967 (37.61)	1.14 (1.04-1.25)	0.007	
≥ 3.5	807 (31.39)	1.26 (0.92-1.72)	0.156	
Smoking History				0.773
Never	1635 (63.59)	1.17 (1.05-1.30)	0.006	
Ever	936 (36.41)	1.22 (1.05-1.41)	0.013	
Alcohol Consumption				0.258
Light	854 (33.22)	1.20 (1.06-1.36)	0.004	
Moderate	1246 (48.46)	1.12 (1.01-1.23)	0.033	
Heavy	471 (18.32)	1.44 (1.21-1.72)	< 0.001	
Physical Activity				0.813
Low	818 (31.82)	1.18 (1.00-1.40)	0.049	
High	1753 (68.18)	1.19 (1.06-1.33)	0.004	
DM				0.100
No	2415 (93.93)	1.22 (1.09-1.36)	< 0.001	
Yes	156 (6.07)	1.04 (0.96-1.13)	0.354	

OR, Odds Ratio; CI, Confidence Interval.

ease burden and bias the representative nature of the sample. Consequently, this design precludes us from distinguishing between long-standing and newly onset hypertension. Se-

cond, residual confounding from unmeasured variables such as dietary sodium intake or stress levels cannot be ruled out. Third, pregnancy status was not explicitly excluded or

adjusted for in our current dataset. Because physiological and hormonal changes during pregnancy can significantly alter weight, lipid profiles, and blood pressure, the inclusion of an unquantified number of pregnant women may introduce potential confounding. Future studies should strictly stratify or exclude pregnant populations to validate these findings. Future prospective cohort studies are needed to evaluate incident hypertension, validate our findings, and further elucidate the pathophysiological pathways linking visceral adiposity to blood pressure dysregulation in this population.

Conclusion

In summary, this cross-sectional study based on 11 cycles of NHANES data (1999-2023) demonstrated a significant nonlinear and threshold-dependent association between Visceral Adiposity Index (VAI) and hypertension among women of reproductive age in the United States. The odds of hypertension increased with rising VAI levels. These findings suggest that VAI may serve as a practical and independent observational marker for early identification of hypertension susceptibility in reproductive-age women. Further prospective cohort studies and basic mechanistic research are warranted to validate these results and establish causality. In the future, maintaining VAI below the identified 1.285 threshold could be considered in early cardiovascular prevention discussions for young women.

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Disclosure of conflict of interest

None.

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