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Association of visceral adiposity index and chronic pain in US adults: a cross-sectional study

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The Visceral Obesity Index (VAI) is utilized as a metric employed to assess the distribution of abdominal adipose tissue as well as the functional status of adipose tissue. Nevertheless, the interplay between VAI and persistent pain has yet to be investigated. This cross-sectional analysis investigated the relationship between VAI and persistent pain among 1357 American adults from NHANES data. A logarithmic transformation of VAI was performed to adjust for skewness. Following the adjustment for relevant variables, logistic regression analysis showed a noteworthy association between VAI and chronic pain, suggesting that higher VAI values may be linked to an increased prevalence of persistent pain. Curve fitting analysis revealed a nonlinear correlation, with a breakpoint at a VAI value of 0.18. For VAI values below this threshold, each unit increase was notably correlated with an elevated prevalence of persistent pain, while increases in VAI beyond this threshold did not show a significant impact on chronic pain prevalence. Subgroup analyses indicated that the VAI may serve as a relatively independent risk factor for persistent pain. These findings highlight the possibility of incorporating abdominal adipose modification into pain management approaches and emphasize the critical importance of monitoring visceral fat accumulation to better identify patients more susceptible to chronic pain.

Keywords Obesity, Visceral adiposity index, Persistent pain, NHANES, Prevalence study

Chronic pain, generally characterized as pain lasting or recurring for more than three months, is characterized by the International Association for the Study of Pain (IASP) as an unpleasant sensory and emotional phenomenon connected to both actual and potential tissue damage. It is classified within the International Classification of Diseases (ICD) as either primary or secondary chronic pain[1,2]. Due to its prolonged duration and complex pathogenesis, Chronic pain is frequently considered a pathological condition in its own right. Patients with chronic pain frequently adjust their expectations from eliminating pain to managing it, aiming for functional and emotional recovery. Research indicates that one in five adults worldwide suffer from moderate to severe persistent pain, significantly impacting their social and professional life quality and placing a substantial strain on medical systems[3–5]. Consequently, early symptom detection and timely intervention are essential strategies to enable the accurate diagnosis and effective management of persistent pain.

The incidence of obesity on a global scale has risen markedly in recent years, posing an increasing public health challenge. Obesity, distinguished by an atypical or excessive accumulation of fat in adipose tissue, is commonly assessed using the Body Mass Index (BMI), established based on a person's weight and height measurements[6,7]. Extensive evidence supports a co-occurrence of obesity and pain, with body fat distribution emerging as a critical factor in chronic pain development[8–11]. However, BMI as a measure of obesity has limitations, as its relationship with body fat percentage is nonlinear and varies by gender. Additionally, BMI fails to consider the heterogeneity in fat distribution, particularly the specific health risks associated with visceral fat[12,13]. Obesity is commonly associated with inflammation of adipose tissue, with visceral fat playing a central role. Severe visceral obesity is frequently linked to low-grade systemic inflammation[14]. Furthermore, research has identified inflammation of both the peripheral nervous system and central nervous system as key contributors to the pathogenesis of chronic pain[15]. To address these limitations, Amato et al. created the VAI as an indirect measure of visceral adiposity and overall obesity, thereby reflecting an individual's metabolic health status[16]. Earlier studies have demonstrated that VAI is linked to diabetes, high blood pressure, stroke, sarcopenia, atherosclerosis, and vascular calcification[17–24]. Nevertheless, the interaction between VAI and chronic pain has yet to be analyzed.

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This research, therefore, strives to examine the connection between VAI and persistent pain in adult participants of the 1999–2004 NHANES and to assess VAI as a novel indicator for risk assessment and preliminary diagnosis in individuals with chronic pain.

Methods

Survey description

The authors utilized data from the NHANES, a national population-based cross-sectional study carried out by the National Center for Health Statistics (NCHS) to analyze health and nutrition trends throughout the United States[25]. NHANES employs a complex, multistage stratified probability sampling method on a biennial cycle to obtain a representative sample of the U.S. population. The NCHS Research Ethics Review Board approved all study protocols, and written informed consent was obtained from each participant or, for those under 16, from a parent or legal guardian. Comprehensive details regarding the NHANES study design and publicly accessible data are available at www.cdc.gov/nchs/nhanes/. This cross-sectional study was conducted in compliance with the STROBE reporting guidelines[26].

Study population

This study utilized data collected during the 1999–2004 cycle of NHANES. Initially, 3,312 participants were recruited for the cohort. Exclusion criteria applied to the following groups: 15,754 participants younger than 20 years, 11,754 individuals who had missing chronic pain data, 2,092 individuals lacking complete data for VAI calculation, and 129 individuals with missing covariate data. After applying these criteria, A sum of 1,357 qualified individuals aged 20 years and above were incorporated into the final analysis (Fig. 1).

Definition of visceral adiposity index and chronic pain

The VAI is a sex-specific measure derived from anthropometric measurements—waist circumference (WC) and BMI—and metabolic parameters—triglycerides (TG) and high-density lipoprotein cholesterol (HDL-C)—used to estimate visceral fat levels. VAI was calculated for each participant using the formulas outlined below: for men, VAI = WC / (39.68 + (1.88 * BMI)) * (1.31 / HDL-C) * (TG / 1.03); for women, VAI = WC / (36.58 + (1.89 * BMI)) * (1.52 / HDL-C) * (TG / 0.81) (14). In this study, VAI was treated as a continuous variable, and participants were divided into quartiles based on their VAI values.

Chronic pain is described as pain that persists or reoccurs for a duration exceeding three months[27]. The identification of patients with persistent pain was conducted using the Miscellaneous Pain Questionnaire (MPQ110). Persistent pain encompasses a broad spectrum of types, including mechanical, musculoskeletal, inflammatory, neoplastic, and neuropathic pain. The pain may affect various anatomical regions, including, but not limited to, the limbs, trunk, head, neck, and face. Participants who indicated a pain duration of "less than one month" or "at least one month but less than three months" were categorized as not experiencing chronic pain. In contrast, those reporting durations of "at least three months but less than one year" or "more than one year" were classified as having chronic pain. Responses marked as "I don't know" or left unanswered were regarded as missing data.

In this study, VAI was designated as the exposure variable, with chronic pain serving as the outcome variable.

Selection of covariates

This Research included various covariates that could shape the interaction between the VAI and chronic pain, encompassing sociodemographic variables such as age, gender, racial or ethnic background, educational attainment, marital status, household income, lifestyle factors (alcohol consumption and smoking status), and coexisting conditions, including coronary heart disease, heart failure, stroke, hypertension, and diabetes mellitus. Race and ethnicity were categorized as non-Hispanic White, non-Hispanic Black, Mexican American, or belonging to another racial group. Education levels were grouped as below 9th grade, 9th to 12th grade, and 12th grade or higher. Household income was categorized by the poverty-to-income ratio (PIR): high (PIR > 3.5), moderate (PIR > 1.3 and ≤ 3.5), and low (PIR ≤ 1.3). Marital status was categorized as married, living independently, or cohabiting with a partner. Smoking status is distinguished between never-smokers, who have smoked fewer than 100 cigarettes in life, and smokers, who have smoked at least 100 cigarettes in life. Never drinkers, are defined as those consuming fewer than 12 drinks per year, and drinkers, are defined as those consuming more than 12 drinks per year. BMI was calculated using an individual's weight and height measurements… Hypertension, coronary artery disease, diabetes mellitus, stroke, and heart failure were determined through participants' self-reported physician diagnoses in the questionnaire. Detailed descriptions of measurement procedures for these variables can be found on the publicly accessible website www.cdc.gov/nchs/nhanes/.

Statistical analysis

Categorical variables were reported in terms of percentages, whereas continuous variables were summarized using the mean and standard deviation (SD) for data that followed a normal distribution. In contrast, for non-normally distributed data, the median and interquartile range (IQR) were utilized, following NHANES analytical guidelines. The VAI was assessed as both a continuous and categorical variable using IQR to categorize the data. T-tests assessed differences in VAI among groups experiencing chronic pain compared to those without chronic pain. For group comparisons, Chi-square tests were applied to analyze categorical variables, while one-way ANOVA was utilized for continuous variables that were normally distributed. For continuous data that exhibited skewness, the Kruskal-Wallis test was employed. Logistic regression models were constructed to Delve into the interaction between VAI and chronic pain. Model 1 was unadjusted for covariates, while Model 2 accounted for age, sex, and race. Model 3 included further adjustments for additional variables such as marital

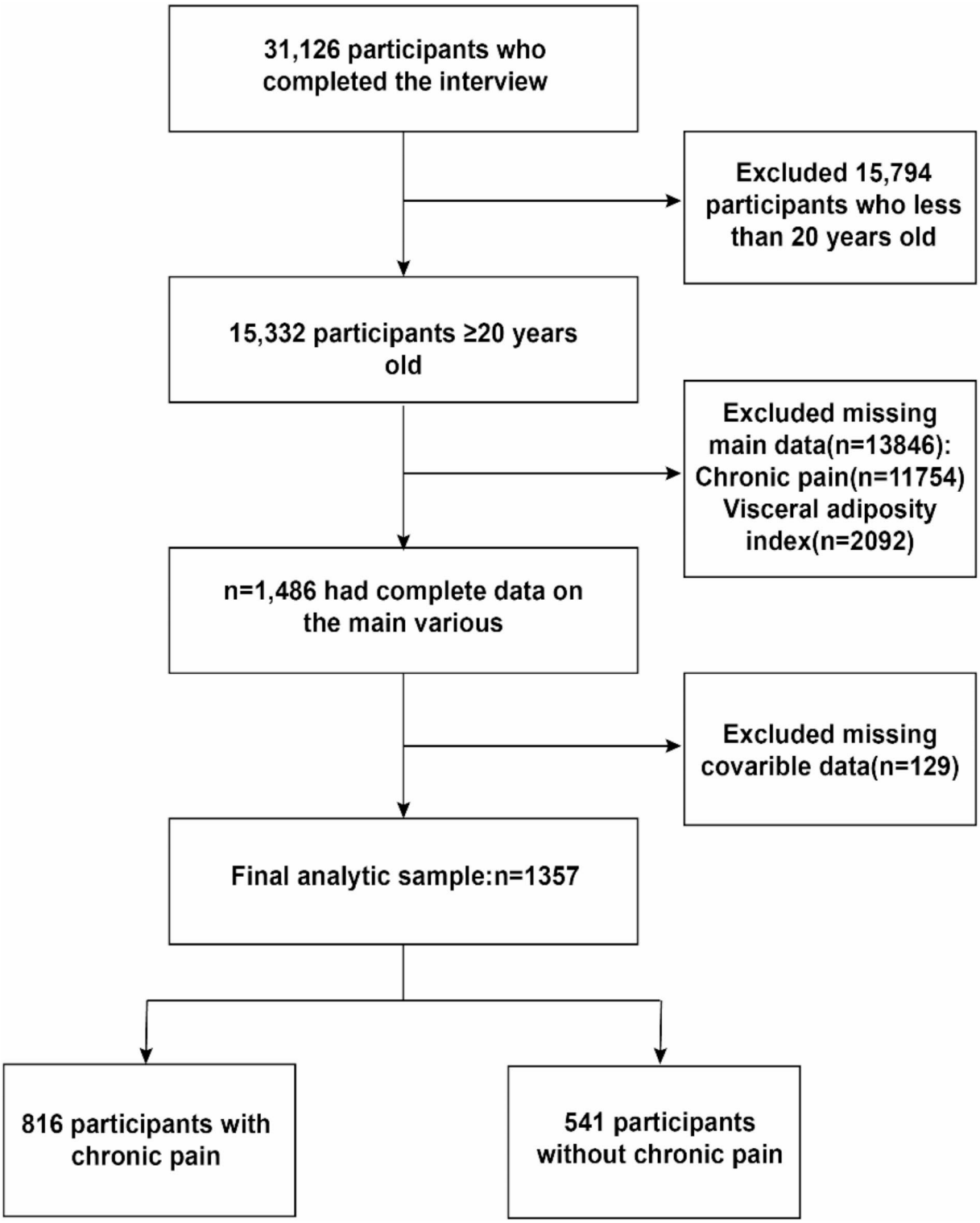

Fig. 1. Flow chart of the inclusion and exclusion of study participants.

status, education level, poverty income ratio (PIR), smoking habits, alcohol consumption, as well as medical conditions like hypertension, diabetes, coronary heart disease, stroke, and heart failure. Smoothed curve fitting was employed to explore possible nonlinear associations between VAI and persistent pain. Subgroup analyses were conducted to examine the interaction between VAI and chronic pain prevalence within each subgroup, adjusting for all other covariates to isolate particular effects on the VAI-chronic pain relationship. Interaction tests were additionally performed to evaluate the stability of associations across different subgroups. We conducted a further evaluation of the ability of VAI and BMI to detect chronic pain by utilizing ROC analysis

and examining the corresponding AUC values. All analyses were conducted using the NHANES-recommended stratification and weighting scheme, with R (version 4.2) and Python (version 3.10.4)[28].

Results

Baseline characteristics of participants

A sum of 1,357 participants from the NHANES (1999–2004) cohort was incorporated into this analysis, comprising 45.62% males and 52.38% females, with a mean age of 49.54 years (± 16.95). The Visceral Adiposity Index (VAI) was divided into quartiles, with ranges of 0.27–1.19 (≤ 1.19) for Quartile 1, 1.19–2.02 (≤ 2.02) for Quartile 2, 2.02–3.37 (≤ 3.37) for Quartile 3, and 3.37–69.67 (≤ 69.67) for Quartile 4. Among the participants, 816(60.13%) reported experiencing chronic pain, with a significant trend showing higher rates of chronic pain across increasing VAI quartiles ($P = 0.002$). Significant variations in age, race, education, marital status, household income, smoking and drinking habits, and prevalence of diabetes and hypertension were observed across VAI quartiles ($P < 0.05$). Individuals in the higher quartiles of VAI were generally older, had lower income, were more likely to be married, had a history of smoking, were less educated, and exhibited higher rates of hypertension and diabetes in comparison with those in the lowest quartile of VAI. Interestingly, alcohol consumption was associated with lower VAI scores ($P < 0.05$). However, no statistically significant differences were found among the VAI quartiles regarding gender, heart failure, stroke, or coronary heart disease. ($P > 0.05$) (Table 1).

Visceral adiposity index and chronic pain

To address the asymmetry in the VAI data, a logarithmic transformation was utilized for the VAI variable. Logistic regression analysis was then performed to examine the link between the transformed VAI (Log VAI) and the incidence of chronic pain. Table 2 presents these findings, indicating that elevated Log VAI values are related to an elevated risk of chronic pain. In the unadjusted analysis, a notable positive association was observed between chronic pain incidence and Log VAI (Model 1: OR 1.86, 95% CI 1.05–2.18). Following incremental adjustment for various confounding variables, The Completely adjusted model still indicated a statistically meaningful positive relationship between Log VAI and a higher incidence of chronic pain (Model 3: OR 1.51, 95% CI 1.05–2.18). To further assess this relationship, Log VAI was divided into quartiles. Elevated quartiles of Log VAI were strongly associated with increased chronic pain incidence (p-trend = 0.004), relative to the lowest quartile. This trend remained robust even after controlling for all covariates, with the highest Log VAI quartile showing a significant positive association with persistent pain incidence (OR 1.50, 95%CI 1.08–2.07; p for trend = 0.033), thereby underscoring a robust positive link between Log VAI and persistent pain.

Nonlinear relationship and threshold effect analysis

Using smoothed curve fitting and analysis of threshold effects, we observed a possible nonlinear interaction. Between Log VAI and chronic pain, exhibiting a reversed L-shaped positive relationship (Fig. 2). Table 3 summarizes the analysis of the threshold effect, revealing an inflection point of 0.18 for Log VAI. According to logistic regression analysis, a rise in Log VAI was significantly linked to a higher incidence of chronic pain when Log VAI was below 0.18 (OR 4.78, 95% CI 1.82–12.60). However, when Log VAI exceeded 0.18, this association was no longer statistically meaningful ($P = 0.729$).

Subgroup analysis

We conducted subgroup analyses and interaction tests considering demographic and lifestyle factors to assess the consistency of the correlation between Log VAI and chronic pain to identify any potential variations across demographic groups (Fig. 3). The link between Log VAI and persistent pain was positive across most subgroups, except among individuals with diabetes, non-drinkers, and participants with lower education levels. This finding reinforces the function of Log VAI as a robust independent risk determinant for chronic pain. Interaction tests indicated no meaningful interactions between Log VAI and gender, education, marital status, age, race, household income, smoking, hypertension, or diabetes ($P > 0.05$), except for drinking status ($P = 0.034$).

Comparison of VAI and BMI in predicting chronic pain

We assessed the predictive ability of VAI and BMI concerning the likelihood of chronic pain by calculating the area under the curve (AUC). The results of the ROC analysis are presented in Fig. 4. The ROC analysis revealed that VAI (AUC = 0.626) outperformed BMI (AUC = 0.607) in predicting the risk of chronic pain.

Discussion

In this cross-sectional study encompassing a diverse population of US adults, the author identified a notable link between VAI and chronic pain. Elevated VAI levels were consistently linked to a greater prevalence of chronic pain across different demographic groups. When VAI was analyzed as a categorized variable, the prevalence of chronic pain was notably greater in the highest quartile (quartile 4) in comparison to the lowest quartile (quartile 1). Smoothed curve fitting and threshold effect analyses further demonstrated an inverted L-shaped relationship between VAI and persistent pain prevalence, with an observed saturation effect at VAI values above 0.18, where the association ceased to be statistically significant ($P = 0.729$). The subgroup analyses provided a deeper exploration of the relationship between VAI and chronic pain within diverse population groups. Generally, the findings demonstrated that the direction of this relationship in the subgroups aligned with that observed in the overall study population. Nevertheless, notable deviations were identified among individuals with diabetes, non-drinkers, and those with lower educational attainment. There are multiple factors that may contribute to this observed phenomenon. One possible explanation is that individuals with lower educational attainment might be more prone to engaging in manual labor and may exhibit a higher threshold for pain perception. Additionally,

Variables	All (*n*=1357)	Q1 (*n*=339)	Q2 (*n*=339)	Q3 (*n*=339)	Q4 (*n*=340)	*p*-value
Age (years)	49.54±16.95	45.90±16.68	49.47±16.68	50.09±17.13	50.09±17.13	<0.001
Gender, n (%)						0.509
Male	619 (45.62%)	151 (44.54%)	145 (42.77%)	162 (47.79%)	161 (47.35%)	
Female	738 (54.38%)	188 (55.46%)	194 (57.23%)	177 (52.21%)	179 (52.65%)	
Race, n (%)						<0.001
Non-Hispanic White	814 (59.99%)	191 (56.34%)	203 (59.88%)	202 (59.59%)	218 (64.12%)	
Non-Hispanic Black	228 (16.80%)	102 (30.09%)	61 (17.99%)	42 (12.39%)	23 (6.76%)	
Mexican American	242 (17.83%)	34 (10.03%)	55 (16.22%)	74 (21.83%)	79 (23.24%)	
Others	73 (5.38%)	12 (3.54%	20 (5.90%)	21 (6.19%)	20 (5.88%)	
Education, n (%)						<0.001
Less than 9th grade	173 (12.75%)	26 (7.67%)	52 (15.34%)	37 (10.91%)	58 (17.06%)	
9–12th grade	234 (17.24%)	49 (14.45%)	48 (14.16%)cc	75 (22.12%)	62 (18.24%)	
12th grade or above	950 (70.01%)	264 (77.88%)	239 (70.50%)	227 (66.96%)	220 (64.71%)	
Marital status, n (%)						0.003
Married	809 (59.62%)	179 (52.80%)	199 (58.70%)	220 (64.90%)	211 (62.06%)	
Living alone	461 (33.97%)	135 (39.82%)	127 (37.46%)	92 (27.14%)	107 (31.47%)	
Living with a partner	87 (6.41%)	25 (7.37%)	13 (3.83%)	27 (7.96%)	22 (6.47%)	
PIR, n (%)						0.005
≥1.30	372 (27.41%)	82 (24.19%)	90 (26.55%)	84 (24.78%)	116 (34.12%)	
>1.30, ≤3.50	545 (40.16%)	128 (37.76%)	132 (38.94%)	155 (45.72%)	130 (38.24%)	
>3.50	440 (32.42%)	129 (38.05%)	117 (34.51%)	100 (29.50%)	94 (27.65%)	
Smoking status, n (%)						0.019
Yes	758 (55.86%)	165 (48.67%)	196 (57.82%)	194 (57.23%)	203 (59.71%)	
No	599 (44.14%)	174 (51.33%)	143 (42.18%)	145 (42.77%)	137 (40.29%)	
Alcohol use, n (%)						0.019
Yes	961 (70.82%)	257 (75.81%)	248 (73.16%)	232 (68.44%)	224 (65.88%)	
No	396 (29.18%)	82 (24.19%)	91 (26.84%)	107 (31.56%)	116 (34.12%)	
Diabetes, n (%)						<0.001
Yes	159 (11.72%)	19 (5.60%)	35 (10.32%)	43 (12.68%)	62 (18.24%)	
No	1198 (88.28%)	320 (94.40%)	304 (89.68%)	296 (87.32%)	278 (81.76%)	
Hypertension, n (%)						<0.001
Yes	496 (36.55%)	102 (30.09%)	110 (32.45%)	135 (39.82%)	149 (43.82%)	
No	861 (63.45%)	237 (69.91%)	229 (67.55%)	204 (60.18%)	191 (56.18%)	
Coronary heart disease, n (%)						0.088
Yes	79 (5.82%)	13 (3.83%)	16 (4.72%)	23 (6.78%)	27 (7.94%)	
No	278 (94.18%)	326 (96.17%)	323 (95.28%)	316 (93.22%)	313 (92.06%)	
Congestive heart failure, n (%)						0.072
Yes	61 (4.50%)	12 (3.54%)	13 (3.83%)	12 (3.54%)	24 (7.06%)	
No	1296 (95.50%)	327 (96.46%)	326 (96.17%)	327 (96.46%)	316 (92.94%)	
Stroke, n (%)						0.169
Yes	56 (4.13%)	11 (3.24%)	9 (2.65%)	17 (5.01%)	19 (5.59%)	
No	1301 (95.87%)	328 (96.76%)	330 (97.35%)	322 (94.99%)	321 (94.41%)	
Chronic pain, n (%)						0.002
Yes	816 (60.13%)	175 (51.62%)	217 (64.01%)	207 (61.06%)	217 (63.82%)	
No	541 (39.87%)	164 (48.38%)	122 (35.99%)	132 (38.94%)	123 (36.18%)	

Table 1. Baseline characteristics of the study population according to visceral adiposity index quartile. Mean ± SD for continuous variables: the P value was calculated by the weighted linear regression model. (%) for categorical variables: the P value was calculated by the weighted chi-square test. *Q* Quartile, *PIR* Ratio of family income to poverty, *VAI* Visceral adiposity index.

those with limited education often have lower health awareness, which can result in inadequate disease screening and delayed diagnoses. Moreover, it is important to acknowledge that the relatively small sample size of the diabetic population could impact the reliability of these findings, necessitating further investigation to better understand this phenomenon in subsequent studies. It is worth noting that the interaction tests revealed no significant associations between Log VAI and variables such as gender, education level, marital status, age, race, income, smoking habits, hypertension, or diabetes. However, drinking status emerged as an exception, showing

	Model 1 OR (95% CI)	*p*-value	Model 2 OR (95% CI)	*p*-value	Model 3 OR (95% CI)	*p*-value
log VAI	1.86 (1.33, 2.61)	<0.001	1.75 (1.23, 2.48)	0.001	1.51 (1.05, 2.18)	0.026
Q1	[Reference]		[Reference]		[Reference]	
Q2	1.67 (1.23, 2.27)	0.001	1.62 (1.18, 2.22)	0.002	1.56 (1.14, 2.15)	0.005
Q3	1.47 (1.08, 1.99)	0.013	1.45 (1.05, 1.98)	0.022	1.40 (1.02, 1.93)	0.037
Q4	1.65 (1.22, 2.25)	0.001	1.56 (1.13, 2.15)	0.007	1.50 (1.08, 2.07)	0.014
p for trend		0.004		0.018		0.033

Table 2. The association between VAI and chronic pain in a multiple logistic regression model. Model 1: No covariates adjusted. Model 2: Adjusted for age, gender, and race. Model 3: Adjusted for age, gender, race, education level, PIR, alcohol status, smoking status, marital status, diabetes, hypertension, coronary heart disease, congestive heart failure and stroke. *CI* Confidence interval, *OR* Odds ratio, *Q* Quartiles, *VAI* Visceral adiposity index.

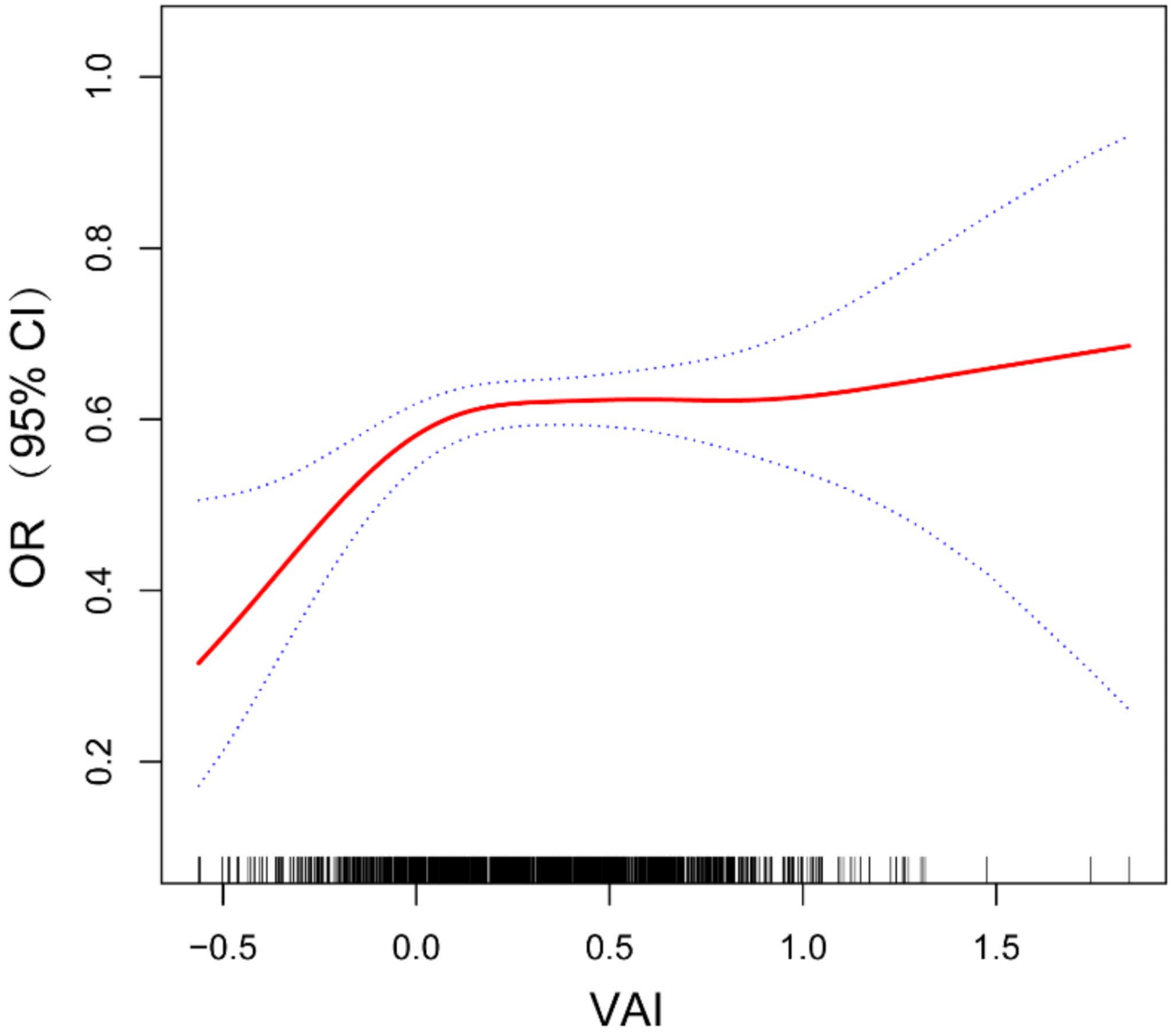

Fig. 2. Smoothing curve fitting of VAI and chronic pain.

a significant interaction. These findings indicate that adopting a healthy lifestyle may effectively decrease the prevalence of chronic pain. Furthermore, to investigate the predictive capability of VAI for chronic pain, we conducted a ROC analysis. The findings revealed that VAI demonstrated superior predictive performance for chronic pain compared to BMI.

Outcomes	Chronic pain	
	OR (95% CIs)	*p*-value
Model a		
(Fitting model by standard logistic regression)	1.51 (1.05, 2.18)	0.026
Model b		
(Fitting models by two-piecewise logistic regression)		
VAI < 0.18	4.78 (1.82, 12.60)	0.001
VAI>0.18	0.91 (0.54, 1.55)	0.729
Likelihood ratio test		0.011

Table 3. Threshold and saturation effect analysis of VAI on chronic pain. The two-piecewise regression models were adjusted for age, race, gender, education level, PIR, alcohol status, smoking status, marital status, diabetes, hypertension, coronary heart disease, congestive heart failure, and stroke. *OR* odds ratios, *95% CI* 95% confidence interval, *VAI* visceral adiposity index.

Our findings highlight the clinical significance of VAI as a potential risk predictor for persistent pain, enhancing the theoretical understanding of the relationship between visceral adiposity and pain. This provides a foundation for prospective longitudinal studies and offers insights for future treatment strategies. To the best of our understanding, this study is the first to explore the relationship between VAI and chronic pain directly. Preceding studies have established an interrelationship between obesity and persistent pain, often highlighting obesity as a predictor of persistent joint and musculoskeletal pain[29,30]. However, the limitations of BMI in assessing visceral adiposity often result in paradoxical findings, where some studies fail to demonstrate a straightforward relationship between obesity and pain[31,32]. Recent studies have demonstrated that VAI offers an advantage over BMI in evaluating obesity and its associated health risks[33–35]. Previous studies have found that obese adults experience an increased prevalence and intensity of pain symptoms, with morbidly obese individuals being four times more susceptible to experiencing persistent pain than their non-obese counterparts[36,37]. Community-based studies also report strong associations between obesity and various types of pain, such as low back pain, migraines, and abdominal pain[38]. Further research has demonstrated that chronic pain disproportionately affects women and older adults and is often associated with obesity[39]. Systematic reviews have likewise found robust associations between obesity and headache, neuropathy, and other forms of chronic pain[40,41]. Our results align with prior research indicating that VAI serves as a reliable predictor in evaluating chronic pain and demonstrates greater predictive accuracy compared to conventional BMI measures.

Several mechanisms may explain the link between VAI and persistent pain, with elevated mechanical loading on weight-bearing joints being one of the most frequently cited factors. Studies have shown that obese individuals experience significantly higher disc pressures when lifting objects, increasing their risk for chronic pain[42]. Additionally, Obesity is believed to promote a low-grade chronic inflammatory state, with visceral adiposity playing a central role. This inflammatory process may modulate pain through elevated levels of interleukin-6 (IL-6), C-reactive protein (CRP), and the accumulation of macrophages in adipose tissue[43–46]. The elevated prevalence of depression in both obesity and chronic pain populations also suggests that depression plays a mediating role in this relationship, research suggests that visceral fat levels may serve as a potential link between metabolic disorders and depression and that treating depression could help mitigate the connection between obesity and chronic pain[38,47]. Lastly, sedentary lifestyle factors are significantly and independently associated with the accumulation of visceral fat and may serve as a common risk factor for both obesity and chronic pain[48–50]. Taken together, these findings suggest that the association between VAI and chronic pain is likely the outcome of various intersecting biological and lifestyle pathways. Future study is necessary to clarify the underlying mechanisms to formulate more effective prevention and therapeutic strategies.

This research possesses several strengths. Firstly, it utilizes nationally representative, population-based sampling data from NHANES, with analyses weighted appropriately to ensure broad applicability. The study's sample size is both representative and statistically robust. Additionally, we controlled for possible confounding factors and conducted subgroup analyses, which enhanced the reliability of our results. Furthermore, we investigated the nonlinear association between VAI and chronic pain, conducting sensitivity analyses to ensure our findings' robustness. However, certain limitations should be noted. Owing to the cross-sectional approach, causal relationships between VAI and chronic pain cannot be established. Despite controlling for multiple covariates, residual confounding by unmeasured factors may still influence our results. Additionally, NHANES chronic pain data are limited to 1999–2004, restricting the study's ability to assess changes over time.

Conclusion

This study demonstrates a notable link between VAI and an increased prevalence of persistent pain among US adults, underscoring the significance of managing visceral fat deposition to identify individuals at heightened risk for persistent pain. Nevertheless, additional large-scale prospective research investigations are required to validate and elucidate these findings.

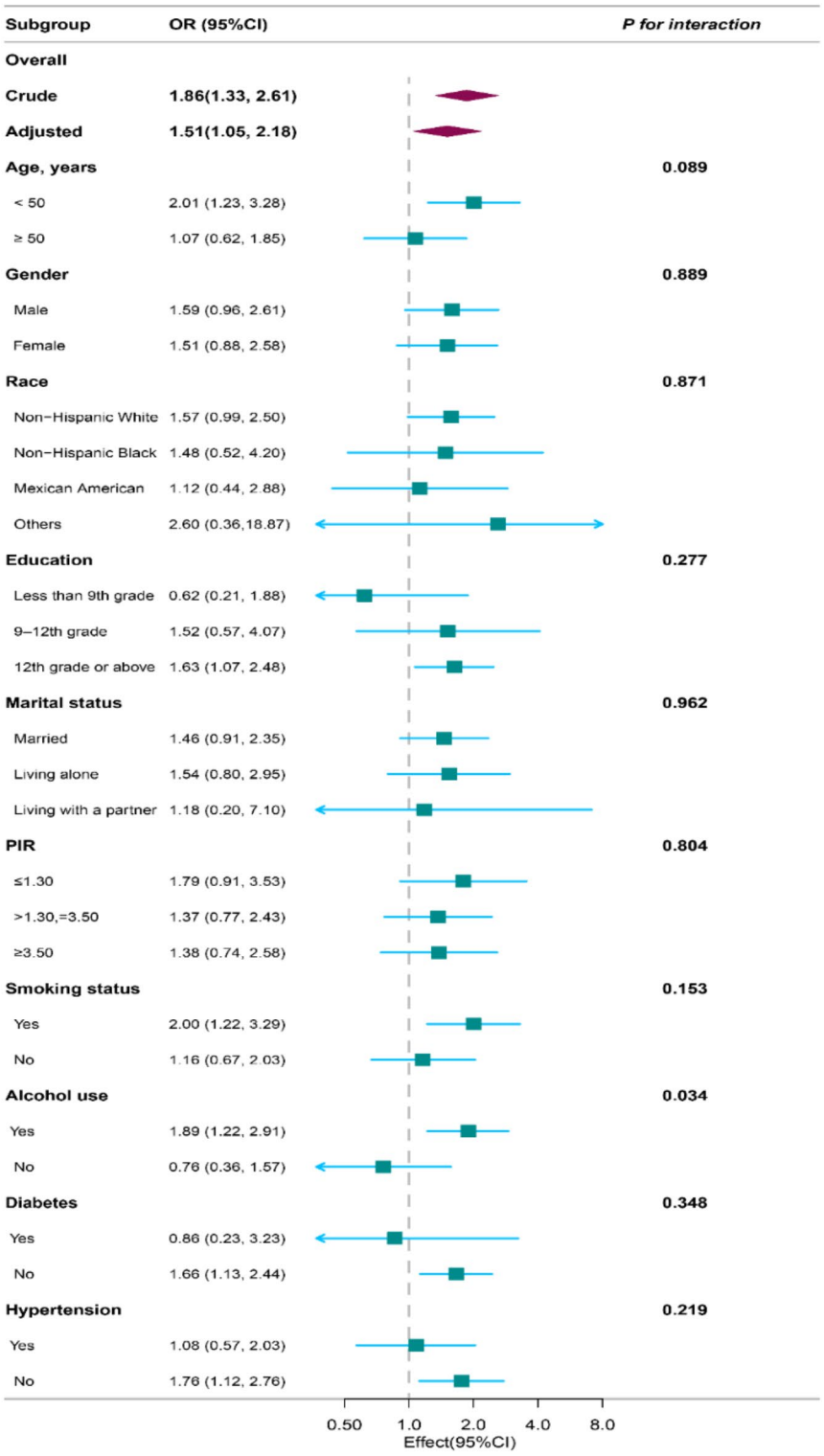

Fig. 3. Subgroup analysis of the association between VAI and chronic pain. Adjusted for age, gender, race, education level, PIR, alcohol status, smoking status, marital status, diabetes, hypertension, coronary heart disease, congestive heart failure, and stroke.

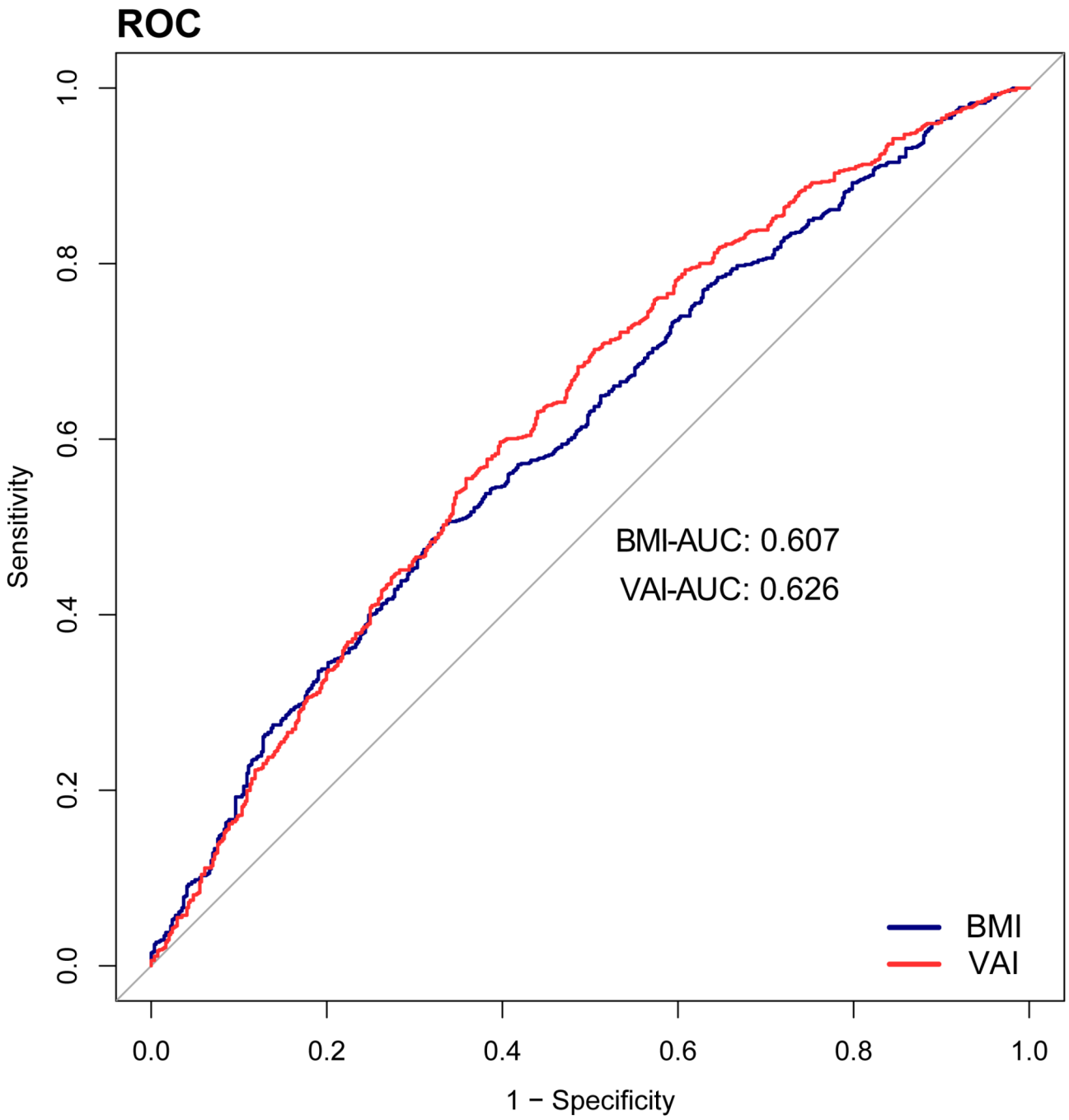

Fig. 4. ROC curves for VAI and BMI prediction of chronic pain.

Data availability

Publicly available datasets were utilized in this research, and the data can be accessed at the following link: https://www.cdc.gov/nchs/nhanes/index.htm.

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W.X: conducted the research and wrote the manuscript. R.S and Y.Z: analyzed the data. W.F: critically revised the manuscript. All authors contributed to the article and endorsed the submitted version.

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Declarations

Competing interests

The authors declare no competing interests.

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