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Association between different visceral fat distribution metrics and risk of abdominal wall hernia

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Abstract

BACKGROUND: Obesity increases the risk of abdominal wall hernia (AWH). Body mass index (BMI) is widely used to define obesity, but it does not reflect fat distribution, especially visceral fat. Therefore, relying solely on BMI may be insufficient for assessing the relationship between obesity and AWH. This study examined the associations of visceral fat area (VFA) and waist circumference (WC) with AWH.

MATERIALS AND METHODS: A total of 417 participants were included in this study, including 209 patients with AWH and 208 healthy controls. VFA and WC were measured by bioelectrical impedance analysis. Multivariable logistic regression, smooth curve fitting, and subgroup analyses were used to evaluate the associations between VFA, WC, and AWH. Additionally, receiver operating characteristic (ROC) curves were used to assess diagnostic performance.

RESULTS: Compared with the controls, AWH patients had significantly higher VFA and WC ($P < 0.001$). After adjustment for potential confounders, both VFA and WC were strongly and positively associated with AWH risk, with evidence of nonlinear relationships. Subgroup analysis demonstrated that the correlation remained consistent across various populations (P-interraction > 0.05). ROC analysis indicated good diagnostic value for both indices (area under the curve: VFA = 0.726; WC = 0.727).

CONCLUSION: Our findings that increased VFA and WC are associated with a higher risk of AWH contribute to our understanding of the relationship between visceral fat distribution and AWH. This finding further supports that keeping VFA and WC within healthy ranges may help prevent AWH. However, inference is limited by the cross-sectional, single-center design and incomplete data on hernia type, defect size, and certain risk factors. Confirmation in multi-center prospective cohorts is needed.

Keywords:

Abdominal wall hernia, visceral fat area, waist circumference

Introduction

Abdominal wall hernia (AWH) is one of the most common diseases worldwide, posing a significant burden on public health.[1,2] Epidemiological data show that the prevalence of AWH is increasing globally, particularly among elderly male populations.[3] The occurrence of AWH significantly reduces patients' quality of life and increases economic burdens and pressure on the healthcare system. The risk factors for the formation of AWH are diverse, including aging, smoking, diabetes, and postoperative infections, among others.[4-6] A comprehensive understanding of the risk factors for AWH is crucial for developing effective prevention and treatment strategies.

Obesity is increasingly prevalent worldwide and places a heavy burden on health systems. Recognized as a chronic disease,

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it involves abnormal fat accumulation and is frequently accompanied by disturbances in lipid metabolism.[7] Evaluation of adiposity commonly uses body mass index (BMI), a standard anthropometric measure.[8] Evidence from multiple studies indicates that elevated BMI is linked to a higher risk of developing AWH.[9-11] However, BMI has significant limitations. It cannot distinguish the ratio of muscle to fat, nor can it reflect the distribution of fat across different parts of the body.[12-15] Increasing studies have indicated that the distribution of fat, particularly the accumulation of visceral fat, is closely related to health risks such as metabolic syndrome, cardiovascular diseases, and certain cancers.[16-18] Consequently, sole reliance on BMI may be insufficient for evaluating obesity and its associated disease risks. The use of BMI to assess obesity and related disease risks may be inadequate. The latest research emphasizes the importance of body composition indicators, such as visceral fat area (VFA) and waist circumference (WC), which more precisely reflect the actual distribution and composition of body fat.[19,20] Research on the relationship between specific body composition indicators and AWH remains limited. Currently, only a few Mendelian randomization studies have explored the causal relationship between fat distribution and AWH, and there is a lack of clinical research. Therefore, it is necessary to conduct large-scale, systematic studies to clarify the relationship between VFA, WC, and other body composition indicators and the risk of AWH.

This study aims to explore the correlation between visceral fat distribution indicators—VFA and WC with AWH. The expected research results are expected to provide new scientific evidence for the prevention and management of AWH.

Materials and Methods

Patients

Between January 2024 and June 2025, 209 patients diagnosed with AWH who had undergone surgical repair at Lanzhou University Second Hospital were enrolled in the AWH group. Concurrently, 208 healthy individuals who underwent routine health examinations at our hospital during the same period were enrolled in the control group. Inclusion criteria for the AWH Group: (1) patient who had undergone surgery; (2) age ≥18 years; (3) preoperative body composition measurement was performed using the InBody 720 device. Exclusion criteria: (1) patients who presented with malnutrition; (2) individuals who were diagnosed with severe organic diseases; (3) individuals who had physical disabilities.

Body composition assessment

Preoperative body composition measurements included parameters such as muscle mass (SLM), BMI, VFA, and WC. All parameters were measured before the operation using the InBody 720 body composition analyzer (Baisbais Body Composition Analysis Co, Seoul, South Korea). The technical principle of this analyzer involves bioelectrical impedance analysis (BIA) to rapidly and non-invasively measure body composition. The threshold values for classification parameters were based on the recommended thresholds provided by the InBody 720 body composition analyzer.

Statistical analysis

In this study, SPSS (Version 26.0, IBM Corp., Armonk, New York, USA) and R software (Version 4.3.2) were used for statistical analysis. Categorical data are expressed as counts or percentages (%), and comparisons between the two groups were made using the chi-square test or Fisher's exact test. Considering the non-normal distribution of continuous variables in the study, results were presented as median and interquartile range [M (Q1, Q3)]. The comparison between the two groups was conducted using the Mann–Whitney *U* test. Three distinct models were established in a multiple logistic regression analysis to assess the correlation between the independent and dependent variables. The first model did not adjust for any variables. The second model adjusted for age and gender, and the third model adjusted for all covariates considered in the study, including age, gender, BMI, and SLM. Furthermore, smoothed curve fitting was employed to explore potential nonlinear relationships between exposure variables and outcome variables. Subgroup analysis was conducted by age, gender, and BMI classification. The Receiver Operating Characteristic (ROC) curve was used, and the area under the curve (AUC) was calculated to investigate the diagnostic efficacy of visceral fat distribution indicators in AWH. A two-tailed $P < 0.05$ was considered statistically significant.

Results

Details of the essential characteristics of participants

A total of 417 participants were enrolled in this study, consisting of 209 patients with AWH and 208 healthy controls. Among the participants, 310 were male and 107 were female. There were 155 individuals aged 60 years or older and 118 individuals with a high BMI. Compared with the healthy controls, patients with AWH showed distinctive characteristics, including a higher proportion of male patients, a higher proportion of individuals with a high BMI, and higher median values for SLM, VFA, and WC. Significant differences were observed in age ($P < 0.001$), gender ($P < 0.001$), BMI ($P = 0.011$), SLM ($P < 0.001$), VFA ($P < 0.001$), and WC ($P < 0.001$) between patients with AWH and healthy controls. Table 1 provides a detailed summary of the demographic characteristics.

Correlations of visceral fat area and waist circumference with abdominal wall hernia

In the original model (Model 1), without adjusting for any confounding factors, both VFA (for every increase of 1 cm^2) and WC (for every increase of 1 cm) were significantly positively correlated with the risk of AWH (VFA: odds ratio [OR] = 1.026, 95% confidence interval [CI] 1.019–1.034, $P < 0.001$; WC: OR = 1.133, 95% CI 1.097–1.172, $P < 0.001$). When analyzed hierarchically by quartiles, compared with the lowest quartile (Q1), the risk of disease in the highest quartile (Q4) of VFA and WC increased sharply (VFA-Q4 vs Q1: OR = 15.01, 95% CI 7.75–30.56, $P < 0.001$; WC-Q4 vs Q1: OR = 9.16, 95% CI 4.92–17.71, $P < 0.001$). After adjusting for age and gender (Model 2), the positive associations between VFA and WC and the risk of AWH remained significant (VFA: OR = 1.020, $P < 0.001$; WC: OR = 1.111, $P < 0.001$). In the quartile analysis, although the association strength in the intermediate-level groups (Q2, Q3) weakened and was no longer statistically significant ($P > 0.05$), the risk in the highest quartile (Q4) remained significant (VFA-Q4: OR = 8.19, 95% CI 3.89–17.94, $P < 0.001$; WC-Q4: OR = 5.65, 95% CI 2.80–11.72, $P < 0.001$). After further adjusting for BMI and SLM (Model 3), the risk per unit increase in VFA and WC, as well as the significant high risk in the highest quartile (Q4), remained independently significant (VFA: OR = 1.020, 95% CI 1.010–1.030, $P < 0.001$; WC: OR = 1.112, 95% CI 1.059–1.172, $P < 0.001$; VFA-Q4: OR = 9.52, 95% CI 3.79–25.34, $P < 0.001$; WC-Q4: OR = 5.60, 95% CI 2.06–16.04, $P < 0.001$). All P trends were statistically significant [Table 2]. Furthermore, we plotted the smooth curves of VFA and WC with AWH [Figure 1]. The results showed that the correlations of VFA and WC with AWH were not linear, and the risk of AWH increased significantly with the increase in VFA or the thickening of WC.

Table 1: The baseline population characteristics of the population in this study

Variables	Total (n = 417)	Control (n = 208)	AWH (n = 209)	P
Age (years)				<0.001
<60	262 (62.8%)	147 (70.7%)	115 (55%)	
≥60	155 (37.2%)	61 (29.3%)	94 (45%)	
Gender				<0.001
Male	310 (74.3%)	126 (60.6%)	184 (88%)	
Female	107 (25.7%)	82 (39.4%)	25 (12%)	
BMI (kg/m^2)				0.011
18.5–23.9	282 (67.6%)	154 (74.1%)	128 (61.3%)	
<18.5	17 (4.1%)	9 (4.3%)	8 (3.8%)	
≥23.9	118 (28.3%)	45 (21.6%)	73 (34.9%)	
SLM (kg)	45.8 (40.4, 50.3)	42.95 (38.60, 47.775)	47.60 (44.35, 52.350)	<0.001
VFA (cm^2)	90 (64.5, 113)	76.50 (50.00, 96.50)	102.00 (79.50, 123.00)	<0.001
WC (cm)	80.2 (76.4, 85.9)	78.50 (74.35, 80.875)	84.00 (78.30, 89.20)	<0.001

AWH = abdominal wall hernia, BMI = body mass index, SLM = such as muscle mass, VFA = visceral fat area, WC = waist circumference

Table 2: Multivariate logistic regression was used to explore the correlations of visceral fat area (VFA) and waist circumference (WC) with abdominal wall hernia

Variables	Model 1		Model 2		Model 3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
VFA	1.026 (1.019,1.034)	<0.001	1.020 (1.012,1.028)	<0.001	1.020 (1.010,1.030)	<0.001
VFA Quartile						
Q1	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Q2	2.431 (1.366,4.400)	0.003	1.708 (0.902,3.252)	0.101	1.882 (0.956,3.752)	0.069
Q3	2.980 (1.669,5.423)	<0.001	1.666 (0.847,3.305)	0.141	1.758 (0.863,3.636)	0.123
Q4	15.014 (7.746,30.563)	<0.001	8.193 (3.885,17.938)	<0.001	9.516 (3.789,25.338)	<0.001
P trend	<0.001		<0.001		<0.001	
WC	1.133 (1.097,1.172)	<0.001	1.111 (1.073,1.153)	<0.001	1.112 (1.059,1.172)	<0.001
WC Quartile						
Q1	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Q2	1.155 (0.649,2.062)	0.624	0.903 (0.478,1.695)	0.750	0.869 (0.450,1.668)	0.674
Q3	2.545 (1.456,4.509)	0.001	1.789 (0.956,3.362)	0.069	1.563 (0.790,3.104)	0.199
Q4	9.164 (4.922,17.710)	<0.001	5.654 (2.804,11.723)	<0.001	5.598 (2.063,16.038)	<0.001
P trend	<0.001		<0.001		<0.001	

Model 1, crude model; Model 2, adjusted for age, gender; Model 3, adjusted for age, gender, BMI= body mass index, SLM = such as muscle mass, CI = confidence interval

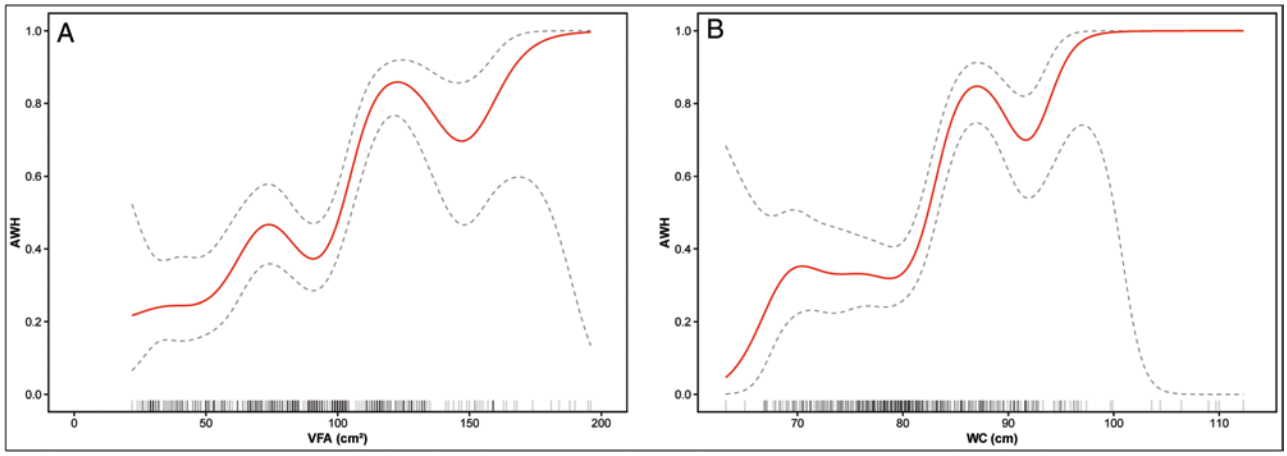


Figure 1: Correlation between different evaluation indicators and abdominal wall hernia (AWH): (A) Association between visceral fat area and AWH; (B) Association between waist circumference and AWH. The red solid line represents the smoothed fitted curve between the variables. The gray dashed band indicates the 95% confidence interval of the fit

Table 3: Detailed results of subgroup analyses

Variables	VFA		*P*-interaction	WC		*P*-interaction
	OR (95% CI)	*P*		OR (95% CI)	*P*	
Age (years)						
<60	1.029 (1.019,1.039)	<0.001	0.202	1.153 (1.101,1.207)	<0.001	0.260
≥60	1.020 (1.009,1.030)	<0.001		1.109 (1.056,1.165)	<0.001	
Gender						
Male	1.022 (1.013,1.031)	<0.001	0.762	1.122 (1.078,1.169)	<0.001	0.119
Female	1.019 (1.00,1.035)	0.019		1.050 (0.976,1.130)	0.188	
BMI (kg/m²)						
18.5–23.9	1.028 (1.018,1.038)	<0.001	0.184	1.200 (1.132,1.272)	<0.001	0.814
<18.5	1.107 (1.003,1.222)	0.044		1.359 (0.915,2.018)	0.128	
≥23.9	1.034 (1.019,1.049)	<0.001		1.206 (1.116,1.303)	<0.001	

BMI = body mass index, VFA = visceral fat area, WC = waist circumference, CI = confidence interval

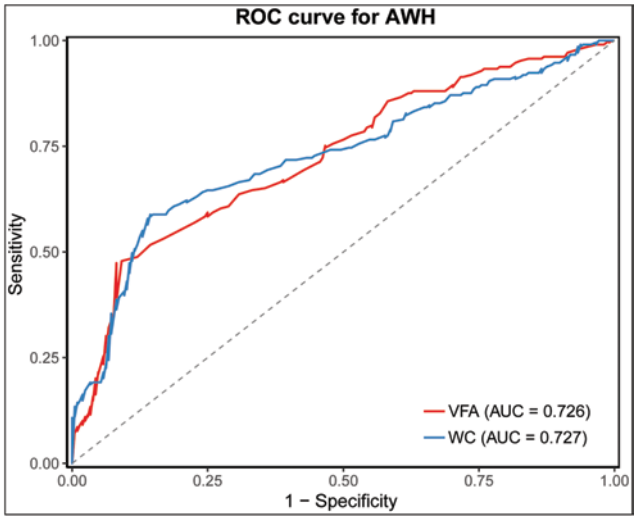


Figure 2: Receiver operating characteristic curves of different indicators for predicting abdominal wall hernia. ROC = receiver operating characteristic; AUC = area under the curve

Details of subgroup analysis

To evaluate the consistency of the associations between VFA, WC, and AWH among diverse demographic groups, we performed subgroup analyses by age, gender, and BMI. After full adjustment for confounding variables, the results revealed stable and persistent associations between both body composition metrics and AWH risk, with no significant effect modification observed. This association remained consistent across populations (all interaction *P* value > 0.05), as detailed in Table 3.

Diagnostic efficacy of visceral fat area and waist circumference s in abdominal wall hernia

To assess the screening and identification efficacy of VFA and WC for AWH, ROC curve analysis was performed. The results showed that the AUC for VFA and WC in diagnosing AWH were 0.726–0.727, respectively, indicating that both have good diagnostic ability for AWH [Figure 2].

Discussion

There is a significant association between obesity and AWH, with obesity being an important risk factor for AWH. A large number of previous studies investigating

the association between obesity and AWH have used BMI as the assessment index for obesity.[21,22] However, obesity has two main subtypes: general obesity and central obesity.[23] It should also be noted that BMI primarily assesses overall adiposity, but has limitations in distinguishing body fat from muscle composition and in evaluating specific fat distribution patterns. Hemberg *et al*.[24] found that higher BMI and WC reduced the risk of inguinal hernia, and Ravanbakhsh *et al*.[25] reached the same conclusion in the US population, which contradicts previous studies. This contradictory result may be due to the limitations of BMI. As a result, an increasing number of hernia surgeons are gradually shifting their focus from BMI to fat distribution. A Mendelian randomization study found a causal relationship between increased body fat mass, WC, visceral adipose tissue, and hip circumference, and an increased risk of AWH.[26] Another two-sample Mendelian randomization study also found a significant causal relationship between body fat distribution and AWH.[27] The mechanism associating fat distribution with AWH may involve multiple factors. Visceral fat accumulation increases intra-abdominal pressure and exerts continuous mechanical stress on the abdominal wall, leading to weakness in the abdominal wall and hernia formation.[19] Second, Visceral fat is a metabolically active tissue that secretes various pro-inflammatory cytokines, such as interleukin-6 and tumor necrosis factor. These cytokines can inhibit collagen synthesis, thereby impairing the healing of fascia.[28] Additionally, visceral fat accumulation is often accompanied by metabolic disorders, such as metabolic syndrome, which may further exacerbate abdominal wall tissue injury.[29]

Although researchers have increasingly focused on the potential association between visceral obesity and hernia, studies in this field remain limited. Aquina *et al*.[13] found that visceral adiposity, quantified by computed tomography, was strongly linked to incisional hernia occurrence, whereas BMI showed a weaker association. In addition, Clark *et al*.[30] demonstrated that human fat distribution helps predict surgical outcomes and provides a basis for preoperative optimization in patients with incisional hernia, thus supporting the role of fat distribution within the hernia.

In this study, VFA and WC were measured using BIA for the first time. As a direct indicator of visceral fat accumulation, VFA can more accurately reflect the actual content of abdominal fat. As a simple index of abdominal fat accumulation, WC is clinically practical. VFA and WC were measured using BIA in 417 participants, and the correlations between VFA, WC, and the risk of AWH were explored. After controlling for potential confounders such as gender, age, BMI, and SLM, VFA and WC were positively correlated with AWH. Notably, this correlation remained consistent throughout various populations, and VFA and WC performed better than traditional BMI measures in predicting AWH risk. The study also found a significant nonlinear dose-response relationship between the two factors and the risk of AWH. In addition, ROC curve analysis confirmed that VFA and WC have diagnostic value for AWH. These findings provide a new strategy for optimizing early screening strategies for AWH.

However, there are several limitations to our study. First, because it is cross-sectional, causation cannot be determined; it can only suggest an association. Second, although we adjusted for multiple confounders, unmeasured confounders may still have influenced the results. Third, this study included AWH types—inguinal, umbilical, epigastric (linea alba), lumbar, and incisional. Defect sizes vary across types. Limited per-type sample sizes and incomplete size data precluded stratified analyses by hernia type or defect size, which limits clinical interpretability. Furthermore, certain risk factors known to independently contribute to the development of hernias, such as smoking, asthma, and constipation, were not included in the analysis due to limitations in the available data. Finally, this is a single-center study with a limited sample size and geographic limitations, and the results may have been affected by selection bias. Therefore, future multi-center, large-scale prospective studies are needed to enhance the reliability and scientific rigor of the results.

Conclusion

Our findings that increased VFA and WC are associated with a higher risk of AWH contribute to our understanding of the relationship between visceral fat distribution and AWH. This finding further supports that keeping VFA and WC within healthy ranges may help prevent AWH.

Author contributions

RL, QL, WL, and CP contributed to the literature search, acquisition, analysis, and interpretation. RL and QL wrote the first draft of the manuscript. CL designed and guided the research. All authors commented on previous versions of the manuscript and approved the final manuscript.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical policy and Institutional Review Board statement

The study conformed to the principles outlined in the Declaration of Helsinki and received approval from the

Medical Ethics Committee of Lanzhou University Second Hospital (Project: 2025A-672).

Declaration of patient consent

This research protocol has been exempted from the informed consent form procedure that was reviewed by the Ethics Committee of Lanzhou University Second Hospital, so I am unable to provide the declaration of patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Acknowledgment

Not applicable.

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