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Gender Differences of Visceral Fat Area to Hip Circumference Ratio for Insulin Resistance

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Introduction: Not all type 2 diabetes mellitus (T2DM) patients exhibit insulin resistance (IR). Our objective is to identify the most effective sex-specific index for predicting IR in T2DM. This will be achieved through a comparative analysis of the sex-specific attributes of waist to hip circumference ratio (WHR), visceral fat area to hip circumference ratio (VHR), and visceral fat area to subcutaneous fat area ratio (VSR).

Methods: Receiver operating characteristic curve analysis was conducted to estimate the area under the curve for WHR, VHR, and VSR. Subsequently, logistic regression was employed to analyze the relationship between VHR and IR.

Results: There were significant differences between males and females in anthropometric measurements, biochemical data, and obesity prevalence. ROC analysis revealed that the area under the curve (AUC) for predicting male IR was 0.67, 0.71, and 0.62 for WHR, VHR, and VSR, respectively. For females, the AUC values were 0.63, 0.69, and 0.60, respectively. In multivariate logistic regression analysis, adjusting for confounding factors, compared to the lowest tertile of VHR, the odds ratio (OR) of the highest tertile was 2.2 (95% CI: 1.47–3.3, P<0.001) for males and 2.1 (95% CI: 1.24–3.57, P=0.005) for females.

Conclusion: VHR emerges as the most reliable predictor of IR risk in individuals with T2DM.

Keywords: insulin resistance, diabetes, hip circumference, visceral fat area

Introduction

The global incidence of diabetes mellitus, notably type 2 diabetes mellitus (T2DM), has markedly surged in recent years.[1] Visceral obesity stands out as a principal risk factor for both T2DM[2] and insulin resistance (IR).[3] Currently, there's a prevailing understanding that obesity, IR, and T2DM mutually exacerbate each other. Despite IR being a key pathogenic factor in T2DM, not all patients with the condition exhibit IR.

Currently, the normal blood glucose-hyperinsulinemia clamp method (Gold Standard) is regarded as the benchmark for assessing IR. However, its invasiveness and high cost restrict its utility in widespread clinical settings.[4] As a viable alternative, insulin resistance measured by the homeostasis model assessment (HOMA-IR) offers simplicity and cost-effectiveness, making it widely embraced as a reliable measure for evaluating IR.[5] Nevertheless, calculating HOMA-IR necessitates fasting plasma insulin levels, which may be subject to variability due to changes in detection methods, particularly in the specificity of insulin molecule recognition by specific antibodies. This potential source of error could compromise the accuracy of HOMA-IR. Consequently, researchers are exploring the utilization of readily available anthropometric and biochemical variables to assess IR, aiming to overcome these limitations. Previous research has demonstrated that the association between visceral fat and IR surpasses that of other obesity indices such as body mass index (BMI) and waist circumference (WC).[6] Males typically exhibit a higher visceral fat area (VFA) than females, whereas females may have a greater subcutaneous fat area (SFA). This divergence in fat distribution could influence the

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risk of IR.[7] Waist to hip circumference ratio (WHR), visceral fat area to hip circumference ratio (VHR), and visceral fat area to subcutaneous fat area ratio (VSR) are frequently used metrics for evaluating central obesity,[8–10] yet consensus on the superior indicator remains elusive.

Hence, our objective is to identify the most effective sex-specific index for predicting the onset of IR by assessing the sex-specific characteristics of WHR, VHR, and VSR. Furthermore, we assessed whether this indicator serves as an independent risk factor for the development of IR.

Methods

Study Design and Participants

All participants in this retrospective cross-sectional survey were sourced from the Department of Endocrinology at Yuxi People's Hospital, Yunnan Province, spanning from March 2021 to August 2023. Comprehensive laboratory tests were conducted on these participants, and baseline information regarding their lifestyle habits, dietary patterns, and demographics was recorded. After excluding non-T2DM patients and those with incomplete data, a total of 1882 patients were included in the final analysis. This study was ethically approved by the Ethics Committee of the Sixth Affiliated Hospital of Kunming Medical University (No. 2024kmykdx6f003) and adhered to the principles outlined in the Declaration of Helsinki. This study did not involve the collection of personal information from patients. Given that the exemption of informed consent would not adversely affect the rights or welfare of the subjects, we obtained approval for this exemption from the Ethics Committee.

Measurements and Definitions

This study gathered various physical measurements, including systolic blood pressure (SBP), diastolic blood pressure (DBP), height, weight, WC, hip circumference (HC), VFA, and SFA. Blood pressure was measured three times using a standard sphygmomanometer after a 10-minute rest, and the average was recorded. Trained nurses measured height and weight of subjects dressed in light clothing without shoes. BMI was computed by dividing weight in kilograms by the square of height in meters and categorized into normal weight (BMI < 25), overweight (BMI ≥ 25 and < 30), or obese (BMI ≥ 30) groups.[11] WC, measured at the anterior iliac crest level, andHC, measured at the maximum hip circumference, were assessed using inelastic measuring tape. VFA and SFA were determined via direct segmented multi-frequency bioelectrical impedance analysis (HDS-2000, Omron, China), a reliable method for evaluating body fat and lean mass. Measurements were conducted on an empty stomach, concurrently with the blood test. Patients were instructed to stand upright, barefoot, and clad in light attire, ensuring full contact of palms, thumbs, heels, and soles with the electrodes. With arms slightly apart, patients maintained this posture for 3–4 minutes, and data were automatically recorded. WHR was calculated as WC divided by HC, while VHR was calculated as VFA divided by HC, and VSR as VFA divided by SFA.

Fasting blood samples were collected before administering hypoglycemic drugs or insulin and analyzed using the Roche Cobas 6000 automatic biochemical analyzer. Fasting plasma glucose (FPG) levels were measured using the hexokinase method, while total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), and uric acid (UA) were determined using enzyme colorimetry. Serum insulin concentration was quantified via immunoradiometry. HOMA-IR was computed by multiplying FPG (mmol/L) by fasting insulin (μIU/mL) and dividing by 22.5.[12] According to the epidemiological survey in China, IR was defined as HOMA-IR > 2.69.[13]

Statistical Analysis

In this study, participants were stratified by gender and IR status. Continuous variables with a normal distribution were presented as mean ± standard deviation, while those with skewed distributions were described using median and interquartile range. Categorical variables were expressed as percentages (%). Continuous variable analysis employed Student's *t*-test or Mann–Whitney *U*-test, while categorical variable analysis utilized the chi-square test. The area under the curve (AUC) of WHR, VHR, and VSR was estimated via ROC curve analysis. Following identification of the most suitable index for assessing IR risk, demographic and biochemical characteristics of the study population, categorized by VHR tertiles, were compared using one-way analysis of variance (ANOVA) or Kruskal–Wallis test for continuous variables and the chi-square test for categorical variables. Lastly, multivariate logistic regression analysis was performed,

with different covariates analyzed by gender to determine the odds ratios (ORs) and 95% confidence intervals (CIs) for IR prediction. $P < 0.05$ was considered significant. All the analyses were performed with the statistical software packages R (http://www.R-project.org, The R Foundation).

Results

Baseline Characteristics of the Study Population According to Gender the Presence of Incident IR

The retrospective study included 1882 participants, comprising 1199 males and 683 females, with a mean age of 53.9 ± 11.2 years. Significant differences were observed between males and females in various baseline variables, including anthropometric measurements, biochemical data, and obesity prevalence. While males tended to be younger than females, no statistical differences were noted in SFA, HOMA-IR, and LDL-C. However, males exhibited significantly higher BMI, WC, HC, VFA, and other indicators compared to females ($P < 0.001$) (Table 1).

When comparing IR patients with the non-IR group, no statistical difference in age was found between males and females. However, IR patients displayed higher BMI, WC, HC, VFA, SFA, FPG, UA, and TG levels compared to the non-IR group. Additionally, patients with IR exhibited significantly higher WHR, VHR, and VSR compared to the non-IR control group ($P < 0.001$) (Table 2).

WHR, VHR and VSR for the Prediction of Incident IR

ROC analysis revealed that the AUC for predicting male IR was 0.67, 0.71, and 0.62 for WHR, VHR, and VSR, respectively. Correspondingly, the AUC for predicting female IR was 0.63, 0.69, and 0.60 for WHR, VHR, and VSR,

Table 1 Baseline Characteristics of the Study Population According to Gender

Variables	Total (n = 1882)	Male (n = 1199)	Female (n = 683)	P
Age (years)	53.9 ± 11.2	52.6 ± 11.1	56.2 ± 10.9	< 0.001
SBP (mmHg)	122.9 ± 17.0	121.5 ± 16.4	125.2 ± 17.7	< 0.001
DBP (mmHg)	71.9 ± 10.8	73.0 ± 10.6	70.0 ± 10.9	< 0.001
BMI (kg/m^2)	25.5 ± 3.4	25.7 ± 3.1	25.2 ± 3.8	0.002
WC (cm)	89.3 ± 8.7	91.0 ± 7.9	86.2 ± 9.2	< 0.001
HC (cm)	96.0 ± 6.8	96.4 ± 6.3	95.4 ± 7.6	< 0.001
VFA (cm^2)	90.2 ± 36.0	94.5 ± 36.6	82.6 ± 33.6	< 0.001
SFA (cm^2)	176.6 ± 56.7	174.9 ± 51.3	179.7 ± 65.0	0.081
WHR	0.9 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	< 0.001
VHR	0.9 ± 0.3	1.0 ± 0.3	0.9 ± 0.3	< 0.001
VSR	0.5 ± 0.2	0.5 ± 0.1	0.5 ± 0.1	< 0.001
FPG (mmol/L)	9.4 ± 3.7	9.6 ± 3.7	9.0 ± 3.6	0.002
HOMA-IR	4.3 ± 3.4	4.2 ± 3.2	4.5 ± 3.8	0.084
UA (mmol/L)	341.2 ± 89.5	357.5 ± 86.8	312.6 ± 87.0	< 0.001
TC (mmol/L)	4.4 ± 1.2	4.4 ± 1.2	4.5 ± 1.1	0.048
TG (mmol/L)	1.9 (1.3, 2.9)	1.9 (1.3, 3.1)	1.8 (1.3, 2.6)	0.006
HDL-C (mmol/L)	1.1 ± 0.3	1.0 ± 0.3	1.2 ± 0.3	< 0.001
LDL-C (mmol/L)	2.5 ± 0.9	2.5 ± 0.9	2.5 ± 0.9	0.39
BMI, n (%)				< 0.001
Normal Weight	862 (45.8)	501 (41.8)	361 (52.9)	
Over Weight	839 (44.6)	590 (49.2)	249 (36.5)	
Obesity	181 (9.6)	108 (9)	73 (10.7)	

Abbreviations: IR, insulin resistance; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WC, waist circumference; HC, hip circumference; VFA, visceral fat area; SFA, subcutaneous fat area; WHR, waist to hip circumference ratio; VHR, visceral fat area to hip circumference ratio; VSR, visceral fat area to subcutaneous fat area ratio; FPG, fasting plasma glucose; HOMA-IR, insulin resistance measured by the homeostasis model assessment; UA, uric acid; TC, Total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein; LDL-C, low-density lipoprotein.

Table 2 Baseline Characteristics of the Study Population According to the Presence of Incident IR

Variables	Male			Female		
	non-IR (n = 407)	IR (n = 792)	P	non-IR (n = 232)	IR (n = 451)	P
Age (years)	53.4 ± 10.4	52.2 ± 11.5	0.086	56.9 ± 9.6	55.9 ± 11.4	0.241
SBP (mmHg)	118.5 ± 16.6	123.1 ± 16.1	< 0.001	124.2 ± 17.2	125.7 ± 18.0	0.275
DBP (mmHg)	70.5 ± 10.7	74.3 ± 10.4	< 0.001	68.4 ± 9.9	70.8 ± 11.3	0.008
BMI (kg/m^2)	24.4 ± 2.9	26.4 ± 3.0	< 0.001	23.8 ± 3.3	26.0 ± 3.7	< 0.001
WC (cm)	87.3 ± 7.7	92.9 ± 7.2	< 0.001	82.2 ± 7.9	88.3 ± 9.1	< 0.001
HC (cm)	94.4 ± 6.1	97.5 ± 6.1	< 0.001	92.8 ± 6.5	96.7 ± 7.8	< 0.001
VFA (cm^2)	76.9 ± 33.5	103.5 ± 34.8	< 0.001	68.4 ± 30.2	90.0 ± 32.9	< 0.001
SFA (cm^2)	152.7 ± 46.7	186.3 ± 49.9	< 0.001	158.6 ± 58.4	190.5 ± 65.6	< 0.001
WHR	0.9 ± 0.1	1.0 ± 0.1	< 0.001	0.9 ± 0.1	0.9 ± 0.1	< 0.001
VHR	0.8 ± 0.3	1.1 ± 0.3	< 0.001	0.7 ± 0.3	0.9 ± 0.3	< 0.001
VSR	0.5 ± 0.2	0.6 ± 0.1	< 0.001	0.4 ± 0.1	0.5 ± 0.2	< 0.001
FPG (mmol/L)	7.9 ± 3.4	10.4 ± 3.5	< 0.001	7.5 ± 3.6	9.8 ± 3.4	< 0.001
HOMA-IR	1.8 ± 0.7	5.5 ± 3.3	< 0.001	1.9 ± 0.6	5.9 ± 4.0	< 0.001
UA (mmol/L)	345.7 ± 86.1	363.5 ± 86.6	< 0.001	293.0 ± 78.8	322.6 ± 89.4	< 0.001
TC (mmol/L)	4.2 ± 1.1	4.5 ± 1.2	< 0.001	4.5 ± 0.9	4.5 ± 1.2	0.909
TG (mmol/L)	1.4 (1.0, 2.1)	2.3 (1.6, 3.6)	< 0.001	1.4 (1.1, 2.0)	2.0 (1.5, 2.9)	< 0.001
HDL-C (mmol/L)	1.1 ± 0.3	1.0 ± 0.2	< 0.001	1.3 ± 0.3	1.1 ± 0.3	< 0.001
LDL-C (mmol/L)	2.5 ± 0.9	2.4 ± 0.9	0.365	2.6 ± 0.8	2.5 ± 0.9	0.13
BMI, n (%)			< 0.001			< 0.001
Normal Weight	235 (57.7)	266 (33.6)		173 (74.6)	188 (41.7)	
Over Weight	158 (38.8)	432 (54.5)		49 (21.1)	200 (44.3)	
Obesity	14 (3.4)	94 (11.9)		10 (4.3)	63 (14)	

Abbreviations: IR, insulin resistance; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WC, waist circumference; HC, hip circumference; VFA, visceral fat area; SFA, subcutaneous fat area; WHR, waist to hip circumference ratio; VHR, visceral fat area to hip circumference ratio; VSR, visceral fat area to subcutaneous fat area ratio; FPG, fasting plasma glucose; HOMA-IR, insulin resistance measured by the homeostasis model assessment; UA, uric acid; TC, Total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein; LDL-C, low-density lipoprotein.

respectively (Figure 1). Notably, VHR emerged as the superior predictor for IR onset in T2DM patients, regardless of gender, outperforming both WHR and VSR.

Incident IR and Baseline Characteristics According to the Tertiles of VHR

When stratifying patients into three groups based on the third tertile of VHR, we noted that while there was no significant age difference among males (P=0.496), a statistically significant difference was observed among females (P=0.007). Additionally, various indicators including SBP, DBP, BMI, WC, HC, VFA, SFA, UA, and TG exhibited a notable upward trend (P<0.001). Conversely, HDL-C, indicative of cardiometabolic protection, exhibited a reverse trend (P<0.001) compared to markers of adverse metabolic conditions. Furthermore, an increase in VHR corresponded to a higher incidence of obesity (Table 3).

Risk of Incident IR According to VHR

In the multivariate logistic regression analysis, different covariates were applied for each gender. However, regardless of the covariates used, the highest tertile of VHR at baseline significantly correlated with a high risk of IR in both unadjusted and adjusted models. Among males, adjusting for SBP, DBP, and BMI in Model I revealed an OR of 2.59 (95% CI, 1.76–3.83) for the highest tertile (T3) of VHR compared to the lowest tertile (T1). After further adjustment for UA, TC, TG, and HDL-C in Model II, the correlation slightly weakened but remained significant (OR: 2.2, 95% CI: 1.47–3.3, P<0.001). For females, after adjusting for age in Model I, the OR for the highest tertile (T3) compared to the lowest tertile (T1) of VHR was 5 (95% CI, 3.26–7.67). Subsequent adjustment for SBP, DBP, and BMI in Model II slightly weakened the correlation but remained significant (OR: 2.95, 95% CI: 1.78–4.88, P<0.001). Even after further adjustment for UA, TG, and HDL-C in Model III, the relationship persisted (OR: 2.1, 95% CI: 1.24–3.57, P = 0.005) (Table 4).

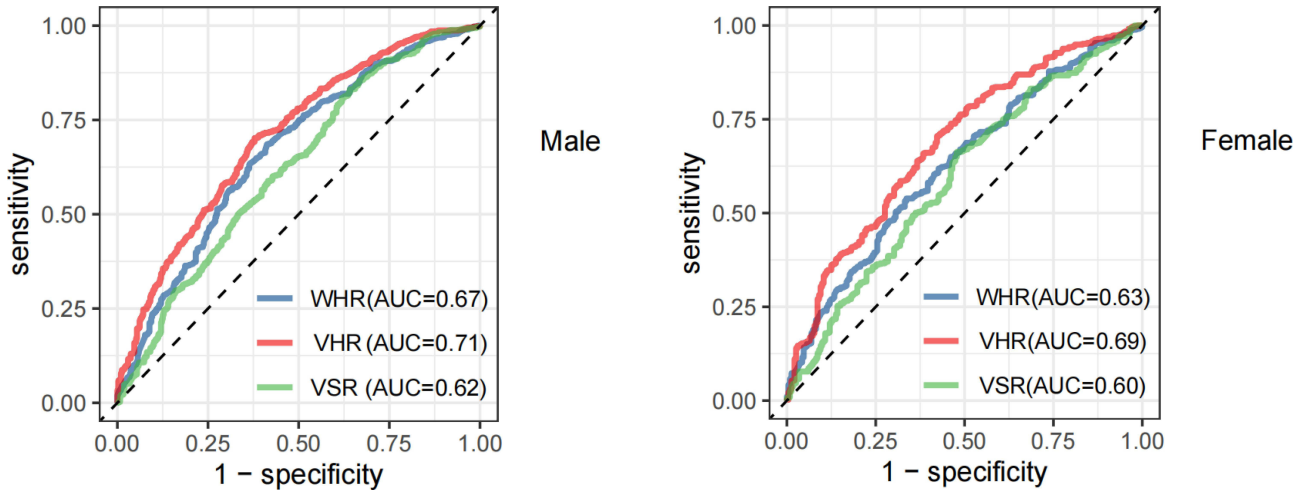

Figure 1 The operating characteristic curves of male and female WHR, VHR and VSR predict the incidence of insulin resistance in type 2 diabetes mellitus. WHR waist to Hip circumference ratio, VHR visceral fat area to hip circumference ratio, VSR visceral fat area to subcutaneous fat area ratio, AUC the area under the curve.

Discussion

In this retrospective study, we assessed the impact of WHR, VHR, and VSR on IR among patients with T2DM. We found that a significant association between higher baseline VHR values and elevated IR risk in both males and females, even after adjusting for various confounding variables.

The application of bioelectrical impedance technology to measure VFA[14] is based on the electrical properties of biological tissues, as different tissues (eg, fat, muscle, water) exhibit varying levels of impedance to electrical currents. In

Table 3 Baseline Characteristics According to the Tertiles of VHR in Male and Female

Variables	Male				Female			
	T1 (n = 400)	T2 (n = 399)	T3 (n = 400)	P	T1 (n = 228)	T2 (n = 227)	T3 (n = 228)	P
Age (years)	52.8 ± 11.2	52.9 ± 10.5	52.1 ± 11.6	0.496	54.4 ± 10.5	57.1 ± 10.1	57.1 ± 11.7	0.007
SBP (mmHg)	117.3 ± 16.1	121.4 ± 16.1	125.9 ± 15.9	< 0.001	120.7 ± 17.1	125.8 ± 17.3	129.1 ± 17.8	< 0.001
DBP (mmHg)	70.1 ± 10.3	73.0 ± 10.5	75.9 ± 10.4	< 0.001	68.5 ± 9.8	70.0 ± 11.2	71.5 ± 11.4	0.015
BMI (kg/m^2)	23.5 ± 2.3	25.6 ± 2.2	28.1 ± 3.0	< 0.001	22.9 ± 2.9	24.9 ± 2.8	27.9 ± 3.7	< 0.001
WC (cm)	84.8 ± 6.3	91.4 ± 5.4	96.9 ± 6.6	< 0.001	79.6 ± 7.0	85.8 ± 6.4	93.3 ± 8.3	< 0.001
HC (cm)	93.1 ± 5.7	96.5 ± 5.0	99.7 ± 6.2	< 0.001	91.9 ± 6.5	94.9 ± 6.5	99.3 ± 7.8	< 0.001
VFA (cm^2)	55.7 ± 18.1	93.7 ± 10.1	134.2 ± 22.4	< 0.001	48.8 ± 14.7	79.8 ± 9.2	119.3 ± 24.2	< 0.001
SFA (cm^2)	134.5 ± 34.3	173.8 ± 33.0	216.4 ± 47.7	< 0.001	141.1 ± 49.1	176.0 ± 47.4	221.8 ± 68.9	< 0.001
FPG (mmol/L)	9.1 ± 4.1	9.5 ± 3.5	10.0 ± 3.4	0.004	8.6 ± 3.8	9.2 ± 3.8	9.3 ± 3.3	0.077
HOMA-IR	3.0 ± 2.3	4.1 ± 2.6	5.5 ± 3.9	< 0.001	3.6 ± 3.6	4.6 ± 4.0	5.4 ± 3.6	< 0.001
UA (mmol/L)	331.4 ± 80.8	358.9 ± 82.3	382.0 ± 89.7	< 0.001	288.8 ± 85.3	314.2 ± 80.6	334.8 ± 89.1	< 0.001
TC (mmol/L)	4.2 ± 1.0	4.4 ± 1.1	4.5 ± 1.4	0.009	4.4 ± 0.9	4.6 ± 1.1	4.5 ± 1.2	0.163
TG (mmol/L)	1.5 (1.0, 2.1)	2.0 (1.4, 3.5)	2.4 (1.6, 3.7)	< 0.001	1.4 (1.1, 1.9)	1.9 (1.5, 2.6)	2.1 (1.6, 3.0)	< 0.001
HDL-C (mmol/L)	1.1 ± 0.3	1.0 ± 0.2	1.0 ± 0.2	< 0.001	1.3 ± 0.3	1.2 ± 0.3	1.1 ± 0.3	< 0.001
LDL-C (mmol/L)	2.5 ± 0.9	2.4 ± 0.8	2.5 ± 0.9	0.618	2.5 ± 0.8	2.5 ± 0.9	2.5 ± 0.9	0.644
BMI, n (%)				< 0.001				< 0.001
Normal Weight	291 (72.8)	157 (39.3)	53 (13.2)		182 (79.8)	129 (56.8)	50 (21.9)	
Over Weight	108 (27)	232 (58.1)	250 (62.5)		42 (18.4)	89 (39.2)	118 (51.8)	
Obesity	1 (0.2)	10 (2.5)	97 (24.2)		4 (1.8)	9 (4)	60 (26.3)	

Abbreviations: VHR, visceral fat area to hip circumference ratio; IR, insulin resistance; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WC, waist circumference; HC, hip circumference; VFA, visceral fat area; SFA, subcutaneous fat area; FPG, fasting plasma glucose; HOMA-IR, insulin resistance measured by the homeostasis model assessment; UA, uric acid; TC, Total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein; LDL-C, low-density lipoprotein.

Table 4 Adjusted or with 95% CI for IR According to the VHR Tertile

Tertiles	Non-adjusted Model OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Male				
Tertile 1	Ref.	Ref.	Ref.	-
Tertile 2	2.39 (1.79~3.19)	1.71 (1.26~2.33)	1.4 (1.02~1.94)	-
Tertile 3	5.36 (3.87~7.41)	2.59 (1.76~3.83)	2.2 (1.47~3.3)	-
P	<0.001	<0.001	<0.001	-
Female				
Tertile 1	Ref.	Ref.	Ref.	Ref.
Tertile 2	2.45 (1.67~3.59)	2.59 (1.75~3.82)	2.09 (1.39~3.15)	1.62 (1.06~2.49)
Tertile 3	4.7 (3.08~7.16)	5 (3.26~7.67)	2.95 (1.78~4.88)	2.1 (1.24~3.57)
P	<0.001	<0.001	<0.001	0.005

Notes: Male Model 1: Adjusted for SBP+ DBP+ BMI; Model 2: Adjusted for Model 1+UA+ TC+ TG+ HDL-C; Female Model 1: Adjusted for age; Model 2: Adjusted for Model 1+ SBP+ DBP+ BMI; Model 3: adjusted for Model 2+ UA+ TG+ HDL-C.

Abbreviation: VHR, visceral fat area to hip circumference ratio; IR, insulin resistance.

this method, a weak alternating current is applied to the body, and the impedance is measured to estimate body composition. Specifically, low-frequency currents are passed through specific body parts (such as the limbs), and the extent to which different tissues hinder the current is detected—muscle has high conductivity, while fat slows down the signal. Double-scanning technology, which involves measuring twice under different conditions, allows for more accurate assessment of visceral fat content.

Our study revealed several intriguing findings. Despite males generally being younger than females, they exhibited higher values across most physical measurement and laboratory examination metrics compared to females, with statistical significance, particularly in VFA. This discrepancy suggests that males tend to have substantially higher visceral fat areas than females. Physiologically, androgens, such as testosterone, are more active in males, promoting abdominal fat cell formation while inhibiting hip and thigh fat cell formation. Conversely, estrogen predominance in females fosters fat cell development in the buttocks and thighs.[15] This hormonal variance accounts for the observed difference in fat distribution between genders, making abdominal fat accumulation more prevalent in males. Despite having a higher basal metabolic rate, males are more prone to accumulating fat, particularly as visceral fat, compared to females, who are inclined to store it as subcutaneous fat.[16]

Currently, the global prevalence of T2DM has surged, presenting a significant public health challenge.[17] While IR typically precedes T2DM development,[18] not all patients with the condition exhibit IR. Unlike type 1 diabetes, T2DM arises from relatively insufficient insulin secretion, allowing pancreatic function to remain intact in patients.[19] Successful compensatory increases in insulin secretion by islet β cells can maintain normal FPG levels.[20] However, inadequate insulin secretion to counter insulin resistance leads to elevated FPG levels.[21] Identifying predictive factors for IR in T2DM is crucial for devising tailored management strategies. VFA provides a more precise evaluation of health risks associated with visceral fat accumulation than traditional BMI measurements. Even among individuals with normal BMI, excessive visceral fat poses health risks, underscoring the value of measuring VFA. Studies have indicated that WC may be more predictive of T2DM risk than BMI.[22] Similarly, a causal relationship exists between high WHR and type 2 diabetes and cardiovascular risk.[23] Additionally, visceral fat demonstrates a stronger association with IR or type 2 diabetes than other obesity indicators, such as BMI or WC.[24,25] Studies have also identified higher VFA and VSR at baseline as independent risk factors for T2DM development.[25] Moreover, VHR exhibits a positive correlation with IR irrespective of gender, making it a reliable predictor of insulin resistance.[9]

After establishing VHR as the optimal predictor of IR, we further examined its relationship with IR, adjusting for potential confounding factors. The results revealed a consistent positive correlation between VHR and IR across genders, even after adjusting for confounders. However, due to the study's limited size, the age distribution skewed towards middle-aged and elderly individuals, and the lack of age stratification represent significant shortcomings. Some studies

suggest that young individuals with T2DM are more prone to insulin deficiency, while elderly individuals are more susceptible to IR.[26] Additionally, our study focuses solely on a specific population of patients with T2DM, potentially leading to incomplete representation of the results. To address these limitations, future research will replicate and expand the study across different datasets or populations to ensure the stability and universality of the findings.

Conclusion

After comparing WHR, VHR, and VSR in predicting IR risk among patients with T2DM, our study identified VHR as the most effective indicator for forecasting IR risk in this population. Additionally, we observed that VHR's predictive power is more pronounced in males than in females, highlighting its role as a predictor of IR risk. This finding underscores the significance of early detection and intervention of IR in personalized T2DM management strategies.

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