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ORIGINAL ARTICLE

Waist-to-height ratio and body roundness index as predictors of insulin resistance in Pakistani adults: a gender and age stratified analysis

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ABSTRACT

Background: A major risk factor for metabolic syndrome and type 2 diabetes mellitus (T2DM), insulin resistance (IR) is especially common in South Asian populations. One of the main causes of IR, central adiposity, is not well represented by traditional anthropometric measures such as the body mass index (BMI) and waist-to-hip ratio (WHR). Using gender- and age-stratified analyses, this study examines the diagnostic value of the Waist-to-Height Ratio (WtHR) and Body Roundness Index (BRI) in predicting IR in Pakistani adults.

Methods: In this cross-sectional study, 1,592 adults aged 18–70 years were recruited from tertiary care hospitals in Peshawar, Pakistan. IR was defined with a threshold of >2.5 using the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR). WtHR, BRI, BMI, WHR, and Abdominal Volume Index (AVI) were calculated using anthropometric data (height, weight, and waist circumference). Youden Index (J) and Receiver Operating Characteristic (ROC) curves were used to assess diagnostic performance, with subgroup analysis by age (≥60 years vs. ≥60 years) and gender.

Results: WtHR showed the highest area under the curve (AUC = 0.710), followed by BRI (AUC = 0.707). The optimal cut-off for WtHR (0.54) achieved 71% sensitivity and 69% specificity (J = 0.40), while BRI (cut-off: 4.2) yielded 69% sensitivity and 68% specificity (J = 0.37).

Conclusion: WtHR and BRI are better at predicting insulin resistance than traditional indices, especially in younger and female populations. In resource limited environments, such as Pakistan, their non-invasive nature and ease of use make them useful instruments for early IR screening.

Keywords: Insulin Resistance, Metabolic Syndrome, Obesity, Risk Assessment, Waist-Height Ratio

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Introduction

Insulin resistance (IR) is a central feature of many metabolic disorders, including type 2 diabetes mellitus (T2DM), metabolic syndrome, and cardiovascular diseases. It occurs when the body's cells fail to respond adequately to insulin, leading to hyperglycemia and compensatory hyperinsulinemia. Globally, the burden of IR has been increasing, particularly in low and middle-income countries (LMICs) like Pakistan, where sedentary lifestyles,

urbanization, and poor dietary habits have contributed to an alarming rise in obesity and associated metabolic disorders (1,2).

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Central obesity is a significant risk factor for IR and is strongly associated with visceral fat accumulation, which drives systemic inflammation and metabolic dysfunction. Traditional measures such as body mass index (BMI) and waist-to-hip ratio (WHR) have been widely used to estimate obesity and its associated health risks. However, these indices have limitations in accurately predicting IR, as they do not account for body fat distribution. In recent years, more refined anthropometric measures, such as Waist-to-Height Ratio (WtHR) and Body Roundness Index (BRI), have gained attention for their ability to predict metabolic risks with higher sensitivity and specificity.(3, 4)

Research conducted in Asian populations has demonstrated that WtHR and BRI are superior to BMI and WHR in predicting IR and related metabolic disorders. WtHR, a simple ratio of waist circumference to height, has been shown to correlate strongly with visceral fat and metabolic risk, making it an effective screening tool for central obesity and IR. BRI, which combines height and waist circumference into a more complex formula, has also been validated as a robust predictor of IR and cardiovascular risk.(5, 6)

The high incidence of metabolic disorders in Pakistan, which are exacerbated by South Asian-specific lifestyle factors and genetic predispositions, presents a special challenge. There is little research assessing the predictive value of WtHR and BRI in the local context, especially when taking age and gender differences into account, despite the increasing burden of IR. To reduce the risk of long-term complications like diabetes and cardiovascular disease, it is essential to identify practical and efficient tools for early IR detection.

Our study aims to assess the predictive ability of WtHR and BRI for identifying IR in Pakistani adults, with a focus on age- and gender-specific variations using Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) as the reference standard. We would also determine the optimal cut-off values for WtHR and BRI for early detection of insulin resistance in Pakistani adults, using Youden Index (J).d. By addressing the gap in local evidence, this research seeks to provide actionable insights for improving screening strategies and public health interventions targeting metabolic disorders in Pakistan.

Methods

Our study employed a cross-sectional design to evaluate the predictive ability of anthropometric indicators, such as Waist-to-Height Ratio (WtHR) and Body Roundness Index (BRI), for identifying insulin resistance (IR) in Pakistani adults. Participants were recruited from tertiary care urban hospitals of Peshawar, Khyber Pakhtunkhwa to ensure a diverse representation of socio-demographic backgrounds. We have utilized a stratified random sampling technique to ensure equal representation of gender and age groups (<60 y versus≥60 y). The sample size was calculated using CDC Epi Info™ StatCalc for population surveys, based on an authentic IR prevalence of 42 %, derived from a 2023 community-based assessment in Karachi. (7) At 95 % confidence and a 5 % margin of error, it yielded a minimum

sample size of 376; to support subgroup-specific ROC analyses (≥300 participants per stratum), accommodate 10 % loss, and ensure statistical accuracy, we inflated it to 1500. A total of 1500 adults aged 18–70 years were enrolled in the study, and participants were stratified into IR and non-IR groups based on their Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) scores, with a cut-off of HOMA-IR >2.5 used to define IR.

Anthropometric measurements were obtained using standardized digital instruments, including height, weight, and waist circumference (WC). These data were used to calculate Body Mass Index (BMI), Waist-to-Height Ratio (WtHR), and Body Roundness Index (BRI) using standard formulas. Biochemical assessments were conducted using fasting blood samples collected from participants to measure fasting glucose and insulin levels. The HOMA-IR score was calculated using the formula:

HOMA-IR=Fasting insulin (mU/L) × Fasting glucose (mmol/L)/ 22.5

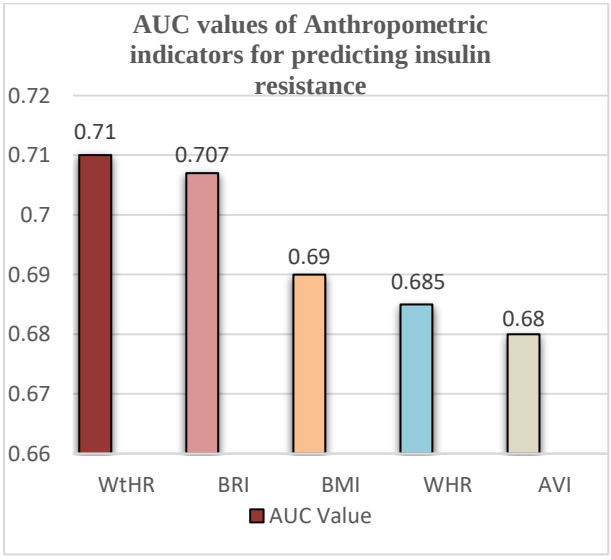
Statistical analysis included Receiver Operating Characteristic (ROC) curve evaluations to determine the diagnostic performance of each anthropometric indicator. The Area Under the Curve (AUC) was calculated to measure the predictive ability of WtHR, BRI, BMI, and Waist-to-Hip Ratio (WHR). Optimal cut-off values for WtHR and BRI were determined using Youden's Index. Additionally, gender and age-specific stratified analyses were conducted to assess the performance of these indicators in subgroups, such as men versus women and individuals above or below 60 years of age.

Data were analyzed using SPSS and R software, with statistical value set at **P < 0.05**. Ethical approval for the study was obtained from an institutional review board of Alliance Health Care via letter number 164/RC/NWSM/2024. Verbal informed consent was collected from all participants before any data or blood samples were obtained.

Results

A total of 1,592 adults were analysed, comprising 1,061 insulin-resistant (IR) and 531 non-insulin-resistant (non-IR) individuals as defined by HOMA-IR > 2.5. Women represented 54 % of the cohort and men 46 %, with a mean age of 43.5 ± 12.8 years; three-quarters of participants were younger than 60 years.

Multivariable logistic models adjusted for age, gender and physical-activity level revealed that both the waist-to-height ratio (WtHR) and the Body Roundness Index (BRI) were strongly correlated with insulin resistance (IR) (adjusted odds ratios > 2.0, $p < 0.05$). While A Body Shape Index (ABSI) was found to be statistically insignificant ($p > 0.05$), traditional measures like BMI, waist-to-hip ratio (WHR), and abdominal volume index (AVI) showed significant but weaker associations (adjusted odds ratios > 1.5, $p < 0.05$), as shown in the chart no.1.



WtHR had the highest area under the ROC curve (AUC = 0.710), followed by BRI subsequently which was consistent with our previous correlations. The better diagnostic performance of WtHR and BRI in comparison to the HOMA IR reference was further confirmed by the lower AUCs of 0.690, 0.685, and 0.680 obtained by BMI, WHR, and AVI, respectively, as depicted in Fig no.1.

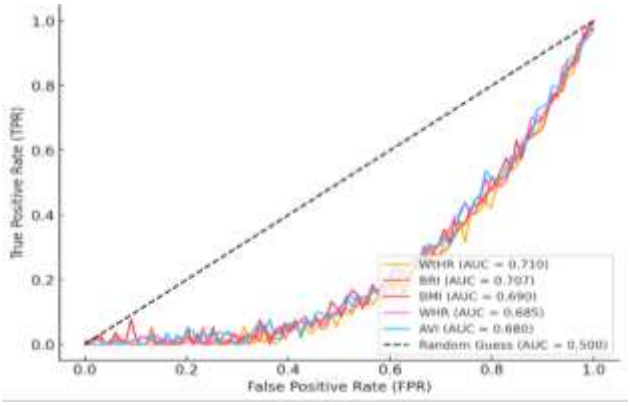


Fig.1 ROC Curve Analysis for the indicators of insulin resistance

Optimal cut-off values. To assess the diagnostic performance of the anthropometric indices for identifying insulin resistance, the Youden Index (J) was calculated using the formula:

$J = \text{Sensitivity} + \text{Specificity} - 1$

For the **Waist-to-Height Ratio (WtHR)**, the sensitivity was 71% and specificity was 69%. Applying the formula:

$J_{WtHR} = 0.71 + 0.69 - 1 = 0.40$

For the **Body Roundness Index (BRI)**, the sensitivity was 69% and specificity was 68%:

$J_{BRI} = 0.69 + 0.68 - 1 = 0.37$

These calculations indicate that WtHR yielded the highest Youden Index (0.40), followed closely by BRI (0.37), suggesting that WtHR may be superior to BRI for detecting insulin resistance in the studied population.

Gender-stratified performance. When analyses were stratified by gender, both WtHR and BRI retained the highest discriminatory power in both genders, but their performance was most pronounced in females (AUCs 0.725 and 0.715, respectively). However, WtHR and BRI continued to be the best predictors in males. WHR and BMI had inferior AUCs of about 0.700, albeit comparatively stronger, as shown in chart no.2.

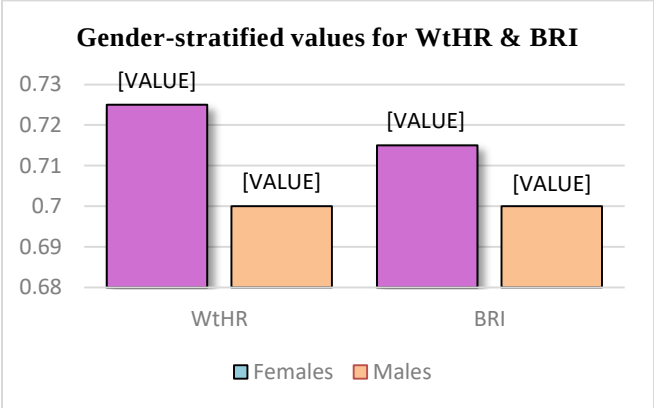


Chart no.2: Area Under the Curve (AUC) values for anthropometric indices stratified by gender in predicting insulin resistance.

Age-stratified performance. Among adults under 60 years, WtHR and BRI maintained high predictive accuracy (AUC > 0.720). In those aged ≥ 60 years, the AUCs for all indices declined modestly; nonetheless, WtHR and BRI continued to outperform BMI, WHR and AVI, as shown in chart no.3.

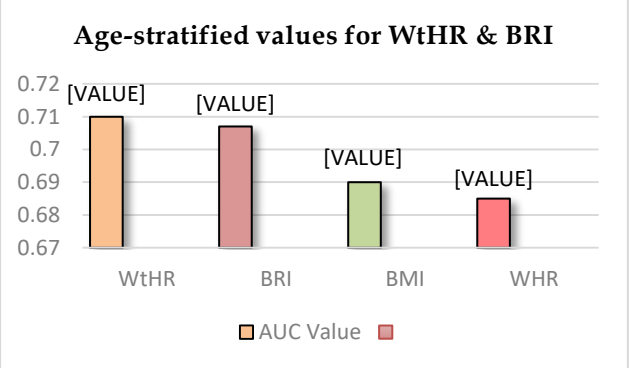


Chart no 3: Age-stratified diagnostic performance (AUC values) of anthropometric indices for predicting insulin resistance.

The conclusive findings demonstrates that WtHR and BRI are the most accurate anthropometric markers of insulin resistance across the sample and within key gender and age strata.

Discussion

Our study shows that waist-to-height ratio (WtHR) and Body Roundness Index (BRI) are markedly more accurate than BMI, waist-to-hip ratio (WHR) or abdominal-volume index (AVI) for identifying insulin resistance (IR) in Pakistani adults, echoing recent evidence that indices centred on central adiposity capture metabolic risk far better than measures of overall size or shape.

In our cohort, WtHR exhibited the greatest diagnostic accuracy (AUC 0.710). Comparable AUCs (~0.71) and virtually identical cut points (0.53–0.54) have been reported in large Chinese and Japanese datasets published since 2024.(8,9) By scaling waist-to-stature, WtHR corrects for body frame, which is critical in South Asian populations that tend to accumulate visceral fat at relatively low BMIs. Our ideal cut-off of 0.54, which results in 71 percent sensitivity and 69 percent specificity, is consistent with community data from Karachi, which shows that WtHR outperformed WHR and BMI for metabolic syndrome screening. (10)

The next most efficient discriminator was BRI (AUC = 0.707). A 2025 meta-analysis in polycystic ovary syndrome also linked higher WtHR and BRI to significantly higher odds of IR, while a 2020 systematic review validated BRI's being superior over BMI, WHR, ABSI, and AVI in predicting metabolic syndrome.(11,12) Our 4.2 threshold reflects values from Eastern Asian cohorts and emphasizes the usefulness of BRI for screening South Asian populations.

As per our study statistics women and adults under 60 years of age had higher discriminatory power for WtHR and BRI. According to stratified analyses, these patterns most likely reflect gender-specific abdominal fat partitioning and age-related changes in body composition with the passage of time. While WtHR and BRI still outperform traditional measures, diagnostic performance can decline in older adults. Young women tend to accumulate proportionately more subcutaneous abdominal fat, which height-normalized waist indices detect more sensitively. (13, 14)

WHR's neglect for height and BMI's incapacity to distinguish between fat and lean tissue limit their applicability for IR screening, particularly in shorter or sarcopenic people. (14) WtHR and BRI, on the other hand, are inexpensive, reagent-free instruments that only need a tape measure and stadiometer, and they can be spread with the straightforward public health message, "Keep your waist below half your height."(15)These indices could significantly enhance early triage for confirmatory biochemical assessment when incorporated into Pakistan's non-communicable disease framework. (16)

WtHR and BRI are effective, low-cost tools for identifying insulin resistance in Pakistani adults and may be particularly beneficial in settings with limited access to laboratory-based diagnostics.(17) Their routine use in clinical practice and public health initiatives may contribute meaningfully to the early detection and prevention of metabolic diseases in Pakistan and similar low and middle-income countries (LMICs).

Conclusion

WtHR and BRI are better at predicting insulin resistance than traditional indices, especially in younger and female populations. In resource limited environments, such as Pakistan, their

non-invasive nature and ease of use make them useful instruments for early IR screening.

Study Limitations and Recommendations

This study has several limitations. The cross-sectional design precludes causal inference, and the sample may not fully represent rural or underserved populations. Future longitudinal studies should evaluate the prognostic value of WtHR and BRI in predicting incident IR and related outcomes over time. Additionally, integrating these anthropometric measures with biochemical markers such as fasting glucose or lipid profiles could enhance risk prediction. Expanding research to include rural populations and diverse ethnic subgroups will also be critical to ensuring broader applicability.

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All the authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed.