



EFFICACY OF SIMPLE ANTHROPOMETRIC TOOLS IN IDENTIFYING INSULIN RESISTANCE AND METABOLIC SYNDROME: EXPERIENCE FROM A RURAL CENTRE IN HYDERABAD

Internal Medicine

Dr. Saad Ali Ibrahim

Department of Medicine, Esani Diabetes and Multispeciality center, Telangana, India

Dr Muzammil Mohammed*

Department of Medicine, Esani Diabetes and Multispeciality center, Telangana, India*Corresponding Author

ABSTRACT

Background and Objectives: The prevalence of insulin resistance (IR) and metabolic syndrome (MetS) continues to rise globally, with low- and middle-income countries disproportionately affected. In rural India, access to sophisticated diagnostic tools is severely limited. This study aimed to retrospectively evaluate insulin resistance and metabolic syndrome in 200 patients at a rural centre in Hyderabad, India, using basic anthropometric tools—height, weight, and waist circumference—and to explore the practical utility of simple indices in resource-constrained settings. **Methods:** A retrospective analysis was conducted on clinical records of 200 patients attending a rural centre in Hyderabad between January 2025 and December 2025. Height, weight, and waist circumference (WC) were collected; body mass index (BMI), waist-to-height ratio (WHtR), and waist-to-hip ratio were calculated. The Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) was used as a surrogate marker for insulin resistance, and metabolic syndrome was diagnosed using the IDF/AHA/NHLBI unified criteria. Fasting blood glucose was measured in mg/dL. Pearson correlation, multiple linear regression, and receiver operating characteristic (ROC) curve analyses were performed to assess the strength of association and predictive performance of anthropometric indices for insulin resistance and metabolic syndrome. A P-value < 0.05 was considered statistically significant. **Results:** Among 200 participants, the prevalence of metabolic syndrome was 42.5% (85 cases), and insulin resistance (HOMA-IR ≥ 2.5) was 48.0% (96 cases). Mean fasting glucose was 102.4 $\pm$ 28.6 mg/dL. Mean WHtR was significantly higher in women than men (0.58 $\pm$ 0.07 vs. 0.54 $\pm$ 0.06, $P < 0.001$). WHtR correlated more strongly with HOMA-IR ($r = 0.412$, $P < 0.001$) than BMI ($r = 0.328$, $P < 0.001$) or WC ($r = 0.387$, $P < 0.001$). ROC analysis showed that WHtR had an area under the curve (AUC) of 0.742 (95% CI: 0.671–0.813) for predicting insulin resistance, with an optimal cut-off of 0.55 (sensitivity 78.1%, specificity 65.4%). The metabolic syndrome group differed significantly from the non-metabolic syndrome group in WHtR, BMI, and WC (all $P < 0.001$). **Conclusions:** In resource-limited rural India, waist-to-height ratio is a simple and effective screening tool for insulin resistance and metabolic syndrome. WHtR ≥ 0.55 can serve as a practical threshold for metabolic risk stratification in rural populations. Incorporating WHtR into routine primary health care assessments may facilitate early identification of high-risk individuals and timely initiation of interventions.

KEYWORDS

Insulin Resistance; Metabolic Syndrome; Waist-to-height Ratio; Rural India; Anthropometry; Resource-limited Settings

INTRODUCTION

The global epidemic of insulin resistance and metabolic syndrome has emerged as one of the most pressing public health challenges of the twenty-first century. Insulin resistance refers to reduced responsiveness of target tissues to the physiological effects of insulin and is a core pathophysiological mechanism underlying type 2 diabetes, non-alcoholic fatty liver disease, and atherosclerotic cardiovascular disease. Metabolic syndrome is a clinical constellation characterised by central obesity, hyperglycaemia, dyslipidaemia, and hypertension, with diagnostic criteria having evolved through multiple iterations (WHO, NCEP ATP III, IDF). The IDF/AHA/NHLBI unified criteria are currently widely adopted.

India occupies a distinctive position in the global map of metabolic diseases. Multiple studies have revealed a concerning "South Asian paradox": Indian populations exhibit significantly elevated insulin resistance and metabolic syndrome risk at relatively lower BMI levels. This "lean metabolic obesity" phenotype suggests that traditional BMI-centred obesity assessment may systematically underestimate risk in South Asian populations. The situation is particularly complex in rural India, where healthcare infrastructure is weak, biochemical testing capacity is limited, and the burden of metabolic diseases is rising rapidly with urbanisation and lifestyle changes [2].

Hyderabad, the capital of Telangana in southern India, and its surrounding rural areas exhibit typical transitional characteristics: traditional dietary patterns coexist with processed food consumption, and physical activity levels decline with mechanisation. However, metabolic risk assessment data for this rural population remain scarce. Existing Indian rural studies have focused primarily on Andhra Pradesh, Rajasthan, or the Mysore region [5,6,8]; systematic data from rural centres around Hyderabad are notably absent.

The methodological positioning of this study is the "pragmatic application of simple tools." In resource-constrained rural health centres, gold-standard methods such as fasting insulin assays and oral glucose tolerance tests are often unavailable. Therefore, identifying reliable, low-cost, grassroots-implementable surrogate indices has important practical significance. Waist circumference and waist-to-

height ratio, as simple surrogate markers of central obesity, have demonstrated significant associations with metabolic risk in multiple populations [3,7]. The unique advantage of WHtR lies in the potential applicability of its "one-size-fits-all" threshold—a fixed cut-off of 0.5 or 0.55 requires no sex- or age-specific reference tables, greatly simplifying grassroots screening [4]. However, the applicability of this threshold in rural Indian populations has not been adequately validated.

The objectives of this study were: first, to describe the prevalence characteristics of insulin resistance and metabolic syndrome among 200 patients at a rural centre in Hyderabad; second, to systematically compare the strength of associations of BMI, WC, and WHtR with insulin resistance and metabolic syndrome; third, to determine the optimal WHtR cut-off for this population; and fourth, to provide evidence-based recommendations for metabolic risk screening in resource-limited settings.

METHODOLOGY AND LITERATURE SELECTION CRITERIA

Study Design and Setting

This was a retrospective observational study using clinical records of adult patients who attended and completed baseline metabolic assessment at the Hyderabad Rural Centre, India, between January 2025 and December 2025. The Hyderabad Rural Centre serves a rural population of approximately 15 surrounding villages, providing primary health care and limited diagnostic services. The centre was selected as the study site because its population characteristics represent the typical socioeconomic and lifestyle conditions of rural Telangana, and it has basic anthropometric and limited biochemical testing capacity.

Study Participants

Inclusion criteria: (1) age ≥ 18 years; (2) completed height, weight, and waist circumference measurements; (3) available fasting blood glucose (mg/dL) and fasting insulin data for HOMA-IR calculation; (4) complete clinical records. Exclusion criteria: (1) type 1 diabetes or known secondary diabetes; (2) pregnant women; (3) severe hepatic or renal impairment; (4) current use of medications that may significantly

affect insulin sensitivity (e.g., glucocorticoids, thiazide diuretics); (5) acute infection or inflammatory state. Of the 200 participants ultimately included in the analysis, 78 (39.0%) were male and 122 (61.0%) were female. The age range was 21–78 years, with a mean age of 46.3 ± 12.7 years.

Anthropometric Measurements

All anthropometric measurements were performed by trained health workers according to standardised protocols. Height was measured to the nearest 0.1 cm (barefoot, standing position, head in the Frankfurt horizontal plane). Weight was measured to the nearest 0.1 kg (light clothing, fasting state). Waist circumference was measured using a flexible steel tape at the midpoint between the lowest rib margin and the iliac crest, at the end of expiration, to the nearest 0.1 cm. Hip circumference was measured at the level of the greater trochanter at the widest point. BMI was calculated as weight (kg) / height (m)². WHtR was calculated as waist circumference (cm) / height (cm). Waist-to-hip ratio (WHR) was calculated as waist circumference / hip circumference.

Biochemical Testing and Insulin Resistance Assessment

Fasting blood glucose was measured by the glucose oxidase method and expressed in mg/dL. Fasting insulin was measured by chemiluminescent immunoassay and expressed in μ IU/mL. Insulin resistance was assessed using the homeostatic model: $\text{HOMA-IR} = [\text{fasting glucose (mg/dL)} \times \text{fasting insulin (}\mu\text{IU/mL)}] / 405$. Based on previous Indian population studies, $\text{HOMA-IR} \geq 2.5$ was defined as insulin-resistant status.

Metabolic Syndrome Diagnostic Criteria

The IDF/AHA/NHLBI 2009 unified criteria were used; metabolic syndrome was diagnosed when any three of the following five criteria were met:

1. Elevated waist circumference (South Asian-specific thresholds: ≥ 90 cm for men, ≥ 80 cm for women)
2. Triglycerides ≥ 150 mg/dL or on lipid-lowering therapy
3. Reduced HDL-C (< 40 mg/dL for men, < 50 mg/dL for women) or on treatment
4. Blood pressure $\geq 130/85$ mmHg or on antihypertensive therapy
5. Fasting glucose ≥ 100 mg/dL or on glucose-lowering therapy

Statistical Analysis

Statistical analysis was performed using SPSS 26.0 and R 4.2.0. Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range), and categorical variables as frequency (percentage). Between-group comparisons used t-tests, Mann-Whitney U tests, or chi-square tests. Correlation analysis used Pearson or Spearman correlation coefficients. Multivariable logistic regression analysed the independent associations of anthropometric indices with metabolic syndrome. ROC curve analysis compared the predictive performance of BMI, WC, and WHtR for insulin resistance and metabolic syndrome, calculating the area under the curve (AUC) and optimal cut-off (Youden index maximisation). Two-sided $P < 0.05$ was considered statistically significant.

Overall Metabolic Characteristics of the Study Population

Among 200 participants, the prevalence of insulin resistance ($\text{HOMA-IR} \geq 2.5$) was 48.0% (96 cases), and metabolic syndrome (IDF/AHA/NHLBI criteria) was 42.5% (85 cases). Comorbidity of both conditions was present in 72 cases (36.0%). Metabolic syndrome prevalence was significantly higher in women than men (50.8% vs. 29.5%, $\chi^2 = 8.74$, $P = 0.003$), while the sex difference in insulin resistance prevalence did not reach statistical significance (men 43.6% vs. women 50.8%, $\chi^2 = 0.99$, $P = 0.319$).

Regarding the metabolic parameter profile, central obesity (by South Asian-specific waist circumference thresholds) was most prevalent at 57.5%. Elevated blood pressure and elevated fasting glucose (≥ 100 mg/dL) were present in 44.0% and 38.5% of participants, respectively. Elevated triglycerides and reduced HDL-C were prevalent in 36.0% and 41.5%, respectively. In the metabolic syndrome group, the proportion with elevated waist circumference reached 94.1%, significantly higher than the 31.3% in the non-metabolic syndrome group ($P < 0.001$).

Association of Anthropometric Indices with Insulin Resistance

Pearson correlation analysis showed that WHtR had the strongest

correlation with log-transformed HOMA-IR ($r = 0.412$, $P < 0.001$), followed by waist circumference ($r = 0.387$, $P < 0.001$) and BMI ($r = 0.328$, $P < 0.001$). Waist-to-hip ratio had a weaker correlation with HOMA-IR ($r = 0.246$, $P < 0.001$). This pattern of associations remained largely consistent after sex stratification, although the correlation between WHtR and HOMA-IR was slightly stronger in women ($r = 0.438$) than men ($r = 0.369$).

In multivariable linear regression analysis with log(HOMA-IR) as the dependent variable, simultaneously including WHtR, BMI, and age, WHtR was an independent predictor ($\beta = 0.284$, $\text{SE} = 0.098$, $P = 0.004$), while BMI's independent effect did not reach significance ($\beta = 0.112$, $\text{SE} = 0.091$, $P = 0.221$). Age ($\beta = 0.018$, $\text{SE} = 0.005$, $P < 0.001$) was also a significant predictor.

ROC Analysis: Best Index for Predicting Insulin Resistance

ROC curve analysis compared the performance of anthropometric indices for predicting insulin resistance ($\text{HOMA-IR} \geq 2.5$). WHtR had an AUC of 0.742 (95% CI: 0.671–0.813), significantly superior to BMI (AUC = 0.658, 95% CI: 0.580–0.736, $P = 0.038$) and waist circumference (AUC = 0.691, 95% CI: 0.616–0.766, $P = 0.112$ vs. WHtR). The optimal WHtR cut-off was 0.55, with sensitivity 78.1%, specificity 65.4%, and Youden index 0.435.

In the female subgroup, WHtR had an AUC of 0.761 (95% CI: 0.672–0.850), with an optimal cut-off also of 0.55. In the male subgroup, the AUC was 0.714 (95% CI: 0.598–0.830), with an optimal cut-off of 0.54; however, given sample size limitations, the robustness of sex-specific thresholds requires further validation.

Comparison of Metabolic Syndrome and Non-Metabolic Syndrome Groups Comparison between the metabolic syndrome group ($n = 85$) and non-metabolic syndrome group ($n = 115$) revealed statistically significant differences in all anthropometric indices. Mean WHtR in the metabolic syndrome group was 0.62 ± 0.06 , significantly higher than 0.52 ± 0.05 in the non-metabolic syndrome group ($t = 12.43$, $P < 0.001$). BMI differences were also significant (29.1 ± 4.8 vs. 24.6 ± 3.9 kg/m², $P < 0.001$), but the effect size (Cohen's $d = 1.03$) was smaller than that of WHtR ($d = 1.82$).

When grouped by WHtR quartiles, metabolic syndrome prevalence showed a clear increasing trend: Q1 (WHtR < 0.48) 8.0%, Q2 (0.48–0.53) 24.0%, Q3 (0.54–0.59) 52.0%, Q4 (≥ 0.60) 86.0% (trend test $P < 0.001$). Insulin resistance prevalence showed a similar gradient (Q1: 16.0%; Q4: 78.0%, $P < 0.001$).

Metabolic Benefits Analysis

When WHtR ≥ 0.55 was used as the screening threshold, the sensitivity for identifying metabolic syndrome was 88.2%, specificity 67.0%, positive predictive value 66.4%, and negative predictive value 88.5%. This means that among individuals with WHtR < 0.55 , nearly 90% could be correctly excluded from having metabolic syndrome. From a public health perspective, this negative predictive value is of significant value for "rule-out screening" strategies in resource-limited settings.

Notably, in the "normal weight" subgroup with BMI < 25 kg/m² ($n = 62$), 21 cases (33.9%) still had metabolic syndrome. These individuals had a mean WHtR of 0.56 ± 0.04 , significantly higher than those in the same BMI range without metabolic syndrome (0.49 ± 0.03 , $P < 0.001$). This finding further confirms the unique advantage of WHtR in identifying "lean metabolic obesity," whereas reliance on BMI alone would miss a substantial proportion of high-risk individuals.

RESULTS

Among 200 participants, 61.0% were female, with a mean age of 46.3 ± 12.7 years. BMI distribution showed normal weight (< 25 kg/m²) in 38.0%, overweight (25–29.9 kg/m²) in 41.5%, and obesity (≥ 30 kg/m²) in 20.5%. By South Asian-specific waist circumference thresholds, central obesity was present in 57.5%. Insulin resistance ($\text{HOMA-IR} \geq 2.5$) prevalence was 48.0%, and metabolic syndrome prevalence was 42.5%. Mean fasting glucose was 102.4 ± 28.6 mg/dL.

WHtR correlated more strongly with all metabolic syndrome components than BMI. Specifically, WHtR correlations with fasting glucose ($r = 0.312$, $P < 0.001$), triglycerides ($r = 0.298$, $P < 0.001$), systolic blood pressure ($r = 0.276$, $P < 0.001$), and HDL-C ($r = -0.341$, $P < 0.001$) were all statistically significant. BMI correlations with these

parameters were weaker (r range 0.156–0.223). Waist circumference correlations were intermediate.

From Q1 to Q4, median HOMA-IR increased from 1.42 (IQR 1.08–1.89) to 3.87 (IQR 2.65–5.42), trend test $P < 0.001$. Metabolic syndrome prevalence increased from 8.0% to 86.0%. Systolic blood pressure, fasting glucose, and triglycerides all showed significant increasing trends, while HDL-C showed a decreasing trend (all $P < 0.001$).

For insulin resistance prediction, WHtR had an AUC of 0.742 with an optimal cut-off of 0.55. BMI had an AUC of 0.658 with an optimal cut-off of 24.8 kg/m². WC had an AUC of 0.691 with an optimal cut-off of 88.5 cm. DeLong's test showed that WHtR's AUC was significantly superior to BMI ($P = 0.038$), while the difference from WC did not reach statistical significance ($P = 0.112$).

For metabolic syndrome prediction, WHtR had an AUC of 0.812 (95% CI: 0.752–0.872) with an optimal cut-off of 0.55. BMI had an AUC of 0.724 (95% CI: 0.653–0.795) with an optimal cut-off of 25.2 kg/m². WHtR was significantly superior to BMI ($P = 0.021$).

With metabolic syndrome as the dependent variable, WHtR, BMI, age, sex, and physical activity level were included in a multivariable logistic regression model. WHtR was the strongest independent predictor of metabolic syndrome (OR per 0.05 increase: 2.34, 95% CI: 1.68–3.26, $P < 0.001$). Age (OR = 1.04, 95% CI: 1.01–1.07, $P = 0.012$) and female sex (OR = 2.18, 95% CI: 1.09–4.36, $P = 0.027$) were also significant predictors. BMI lost statistical significance after inclusion of WHtR (OR = 1.02, 95% CI: 0.94–1.11, $P = 0.642$), suggesting that WHtR mediates the association between BMI and metabolic syndrome.

Using WHtR < 0.55 as the "low-risk" classification criterion, the negative predictive value in this cohort was 88.5%. This means that among individuals with WHtR < 0.55 , only 11.5% had metabolic syndrome. Considering the extremely low cost of WHtR measurement and its independence from laboratory support, this performance has significant practical implications.

In the subgroup with normal BMI (< 25 kg/m²), 38.7% (24/62) had WHtR ≥ 0.55 , of whom 21 (87.5%) were diagnosed with metabolic syndrome. This finding suggests that incorporating WHtR into routine assessment can additionally identify approximately one-third of metabolic syndrome cases among individuals with "normal" BMI.

Fasting Glucose Distribution (mg/dL)

Category	Fasting Glucose (mg/dL)	Number (%)
Normal (< 100 mg/dL)	92.4 ± 6.8	123 (61.5%)
Impaired (100–125 mg/dL)	112.6 ± 7.2	52 (26.0%)
Diabetic (≥ 126 mg/dL)	158.3 ± 24.7	25 (12.5%)
Total	102.4 ± 28.6	200 (100%)

Metabolic Syndrome Component Prevalence (IDF/AHA/NHLBI Criteria)

Component	Criteria	Prevalence (n)	Percentage
Elevated WC	M ≥ 90 cm, F ≥ 80 cm	115	57.5%
Elevated TG	≥ 150 mg/dL	72	36.0%
Reduced HDL-C	M < 40 , F < 50 mg/dL	83	41.5%
Elevated BP	$\geq 130/85$ mmHg	88	44.0%
Elevated FG	≥ 100 mg/dL	77	38.5%

DISCUSSION

This study confirmed three core findings among 200 participants at a rural centre in Hyderabad, India: first, insulin resistance and metabolic syndrome are highly prevalent in this rural population (48.0% and 42.5%, respectively), constituting a major public health burden; second, WHtR outperforms BMI in predicting insulin resistance and metabolic syndrome, performing comparably to or slightly better than waist circumference; third, WHtR ≥ 0.55 can serve as a practical screening threshold for this population, with a high negative predictive value.

These findings are highly consistent with existing evidence from South Asian populations. Vasan et al.'s study in South Indian adolescents and

young adults similarly found waist circumference and abdominal skin fold thickness to be important predictors of metabolic abnormalities, with a negative predictive value of 82.8% for the combined measurement [1]. A Brazilian national study further validated that WHtR outperforms BMI in identifying health risks [9].

The optimal WHtR cut-off in this study was 0.55, slightly higher than the internationally commonly used 0.5 threshold. This difference may reflect the body composition characteristics and metabolic risk distribution of the Indian population. South Asian populations tend to have higher visceral fat content and metabolic risk at the same WHtR level, potentially requiring a slightly higher threshold to balance sensitivity and specificity. In resource-limited settings, the 0.55 threshold provides good sensitivity (78.1%) and reasonable specificity (65.4%), suitable as a primary screening tool.

Regarding the applicability of WHtR in rural Indian populations, existing literature presents relatively consistent evidence. Krupp et al. (2020) reported a metabolic syndrome prevalence of 47.1% among rural women in Mysore, with low HDL being the most prevalent criterion (88.4%), followed by elevated glucose (57.9%) and elevated triglycerides (49.3%) [6]. Prabhakaran et al. (2007) highlighted the urban-rural divide in metabolic syndrome prevalence, framing it as a "problem of urbanization" [2]. Latha et al. (2024) further confirmed the epidemiological pattern of metabolic syndrome in rural South India [8].

However, validation studies of WHtR specifically for the rural Hyderabad centre population have been lacking. This study's contribution lies in filling this geographic and methodological gap, providing data on the optimal WHtR cut-off and predictive performance for this specific population.

It is noteworthy that Sabo et al. (2012), in the Fels Longitudinal Study, suggested that WHtR is not superior to other height-adjusted indices across all age groups. That study found WHtR suitable for some childhood ages (boys: 5–9, 13–16; girls: 4–7, 9, 11–14) but not for adult ages; root-height adjusted waist circumference worked well mostly for older teenage children and adults [3]. This methodological controversy suggests that WHtR's superiority may be population-specific and requires independent validation in different populations. This study's findings in rural Indian adults support WHtR's utility in this specific population but should not be extrapolated to all populations or age groups.

Despite WHtR's demonstrated predictive performance in multiple populations, several important gaps remain in the existing literature that warrant critical scrutiny.

First, the tension between population-specific thresholds and universal applicability. International guidelines tend to recommend WHtR 0.5 as a "one-size-fits-all" threshold, with simplicity being its main advantage [4]. However, this study suggests that 0.55 may be more appropriate in rural Indian populations. This raises a fundamental question: does a truly universal WHtR threshold exist? Or does each major population require independent validation studies? The existing literature lacks systematic comparative analyses addressing this question. Garnett et al.'s (2008) successful validation of the 0.5 threshold in adolescents cannot be automatically generalised to adults or different ethnic groups [4].

Second, the mechanistic basis of the WHtR–insulin resistance association has not been adequately elucidated. As a surrogate marker of central obesity, WHtR's association with insulin resistance may be mediated through lipotoxic effects of visceral fat, altered adipokine secretion, and chronic low-grade inflammation. However, existing literature largely remains at the epidemiological association level, lacking in-depth mechanistic studies. Whether WHtR has equivalent predictive performance across all metabolic phenotypes, or only in specific subgroups (such as "lean metabolic obesity"), remains inadequately addressed.

Third, there is a paucity of longitudinal evidence. The vast majority of studies on WHtR's predictive performance are cross-sectional [1,7], unable to answer whether dynamic changes in WHtR correlate with longitudinal trajectories of metabolic risk. Is the rate of WHtR increase more predictive than a single measurement? Can interventional reduction of WHtR translate into metabolic benefits? These key questions require prospective cohort studies.

Fourth, the practical utility of WHtR in clinical decision-making has not been adequately evaluated. Even if WHtR can accurately identify high-risk individuals, does incorporating it into clinical pathways improve patient outcomes? Is there a complete "screening-intervention" evidence chain? Existing literature focuses primarily on diagnostic accuracy while neglecting implementation science issues.

Fifth, the competitive relationship with novel obesity indices. In recent years, novel indices such as ABSI (A Body Shape Index) and BRI (Body Roundness Index) have been proposed, claiming superior performance to traditional indices in predicting metabolic risk. However, the computational complexity of these novel indices is significantly higher than WHtR, and their practical value in resource-limited settings is questionable.

Limitations of This Study

This study has several limitations that warrant candid acknowledgement. First, the retrospective design limits data completeness and standardisation; some potential confounders (such as diet, physical activity, socioeconomic status) were not systematically collected. Second, the single-centre design limits generalisability; the population characteristics of the Hyderabad Rural Centre may not fully represent other rural areas of India. Third, insulin resistance was assessed using HOMA-IR as a surrogate rather than the gold-standard hyperinsulinaemic-euglycaemic clamp technique, which may introduce classification error. Fourth, the sample size is relatively limited (200 cases), and statistical power for subgroup analyses may be insufficient. Fifth, metabolic syndrome diagnosis relied on IDF/AHA/NHLBI criteria; although widely accepted in Indian populations, controversy remains.

Future Research Directions

Based on the above critical analysis, we propose the following future research directions:

- Priority 1: Multi-centre prospective cohort studies. Establish WHtR validation cohorts across different geographic regions of India to systematically evaluate the sensitivity, specificity, and predictive values of 0.5 and 0.55 thresholds. Follow metabolic outcomes to assess WHtR's longitudinal predictive value.
- Priority 2: WHtR-guided intervention trials. Design randomised controlled trials to evaluate whether intensified lifestyle intervention based on WHtR screening improves metabolic outcomes.
- Priority 3: Mechanistic studies. Combine imaging (CT/MRI visceral fat quantification), adipokine profiles, and inflammatory markers to elucidate the biological basis of the WHtR-insulin resistance association, particularly in the "lean metabolic obesity" phenotype.
- Priority 4: Implementation science research. Evaluate the feasibility, cost, and sustainability of incorporating WHtR into routine primary health care assessments in rural India, and develop WHtR communication tools suitable for low-literacy populations.
- Priority 5: Comparative studies with novel indices. Systematically compare the predictive performance and operational simplicity of WHtR, ABSI, BRI, and other indices in the same population.
- Priority 6: Life-course perspective. Utilise existing birth cohort resources to evaluate the impact of early-life factors on adult WHtR and metabolic risk.

CONCLUSION

This study confirmed among 200 participants at a rural centre in Hyderabad, India, that the prevalence of insulin resistance and metabolic syndrome reached 48.0% and 42.5%, respectively. Waist-to-height ratio outperforms BMI in predicting insulin resistance and metabolic syndrome and performs comparably to waist circumference. $WHtR \geq 0.55$ can serve as a practical screening threshold for this population, with a negative predictive value of 88.5%. Incorporating WHtR into routine primary health care assessments in rural areas is a low-cost, actionable, and potentially high-impact metabolic risk screening strategy. Future research should focus on prospective validation, intervention trials, and mechanistic

exploration to translate the potential of this simple tool into actual health benefits.

REFERENCES:

1. Vasan SK, Thomas N, Christopher S, Geethanjali FS, Paul TV, Sanjeevi CB. Anthropometric measurements for the prediction of the metabolic syndrome: a cross-sectional study on adolescents and young adults from southern India. *Heart Asia*. 2011;3(1):2-7.
2. Prabhakaran D, Chaturvedi V, Shah P, Manhapra A, Jeemon P, Shah B, et al. Differences in the prevalence of metabolic syndrome in urban and rural India: a problem of urbanization. *Chronic Illn*. 2007;3(1):8-19.
3. Sabo RT, Yen MS, Daniels S, Sun SS. Comparing height-adjusted waist circumference indices: the Fels Longitudinal Study. *Open J Endocr Metab Dis*. 2012;2(3):40-6.
4. Garnett SP, Baur LA, Cowell CT. Waist-to-height ratio: a simple option for determining excess central adiposity in young people. *Int J Obes*. 2008;32(6):1028-30.
5. Sharma AK, Baig VN, Ahuja J, Kacker S, Gupta R. Prevalence of metabolic syndrome and risk factors in a rural population of Rajasthan. *J Assoc Physicians India*. 2023;71(3):11-2.
6. Krupp K, Adsul P, Wilcox ML, Srinivas V, Frank E, Srinivas A, et al. Prevalence and correlates of metabolic syndrome among rural women in Mysore, India. *Indian Heart J*. 2020;72(6):582-8.
7. Zhang ZQ, Deng J, He LP, Ling WH, Su YX, Chen YM. Comparison of various anthropometric and body fat indices in identifying cardiometabolic disturbances in Chinese men and women. *PLoS One*. 2013;8(8):e70893.
8. Latha PS, Sangeetha S, Vijayakarhikyan M, Shankar R. Prevalence and influencing factors of metabolic syndrome among rural adult population in a district of South India. *J Family Med Prim Care*. 2024;13(8):3122-8.
9. Corrêa MM, Facchini LA, Thumé E, Oliveira ERA, Tomasi E. The ability of waist-to-height ratio to identify health risk. *Rev Saude Publica*. 2019;53:66.
10. Xu Y, Yan W, Cheung YB. Body shape indices and cardiometabolic risk in adolescents. *Ann Hum Biol*. 2014;42(1):70-5.
11. Raghupathy P, Antonisamy B, Geethanjali FS, Saperia J, Leary SD, Priya G, et al. Glucose tolerance, insulin resistance and insulin secretion in young south Indian adults: relationships to parental size, neonatal size and childhood body mass index. *Diabetes Res Clin Pract*. 2010;87(2):283-92.
12. World Health Organization. STEPwise approach to NCD risk factor surveillance (STEPS) [Internet]. Geneva: WHO; 2024 [cited 2026 Oct 2]. Available from: <https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/steps>.