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COMPARATIVE DIAGNOSTIC PERFORMANCE OF BMI, WAIST CIRCUMFERENCE, WAIST-TO-HEIGHT RATIO, AND NECK CIRCUMFERENCE IN PREDICTING METABOLIC SYNDROME AMONG ADULTS ATTENDING A TERTIARY CARE CENTRE

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ABSTRACT
Background: Metabolic syndrome is a major cardiometabolic health problem, and simple anthropometric measures may facilitate early identification of individuals at increased metabolic risk. Body mass index (BMI) reflects overall adiposity, whereas waist circumference (WC), waist-to-height ratio (WHtR), and neck circumference (NC) provide information regarding regional adiposity.
Methods: A hospital-based cross-sectional analytical study was conducted among 200 adults attending a tertiary care hospital over a six-month period. Demographic and clinical information was collected using a structured proforma. BMI, WC, WHtR and NC were measured using standardized anthropometric techniques. Blood pressure was recorded, and fasting plasma glucose, triglycerides and HDL-cholesterol were estimated. Metabolic syndrome was defined according to harmonized criteria. Descriptive and comparative analyses were performed, followed by correlation analysis, receiver operating characteristic (ROC) analysis and logistic regression. Diagnostic performance was assessed using area under the curve (AUC), sensitivity, specificity and optimal cut-off values.
Results: Metabolic syndrome was identified in 93 (46.5%) participants. BMI, WC, WHtR and NC were significantly higher among participants with metabolic syndrome than those without it ($p<0.001$ for all comparisons). All four anthropometric indices demonstrated significant positive correlations with fasting glucose and triglycerides and inverse correlations with HDL-cholesterol. WHtR demonstrated the highest discriminatory performance for metabolic syndrome, with an AUC of 0.852 (95% CI: 0.801–0.903), followed by WC (AUC 0.816), BMI (AUC 0.797) and NC (AUC 0.712). The optimal WHtR cut-off was >0.529, with 72.0% sensitivity and 86.0% specificity. In adjusted logistic regression analysis, WC demonstrated the strongest independent association with metabolic syndrome (OR 8.63, 95% CI: 4.59–16.23).
Conclusion: WHtR demonstrated the best overall discriminatory performance, while WC showed the strongest independent association with metabolic syndrome. These measures may complement BMI in identifying adults requiring further metabolic assessment, while NC may serve as an additional simple anthropometric marker.

KEYWORDS: Metabolic syndrome; obesity; body mass index; waist circumference; waist-to-height ratio; neck circumference; anthropometry; ROC curve.

INTRODUCTION
Obesity has emerged as one of the most important modifiable determinants of non-communicable diseases worldwide. It is increasingly recognized not simply as excess body weight, but as a chronic disease characterized by abnormal or excessive adipose tissue accumulation with important metabolic consequences. The World Health Organization (WHO) reported that in 2022, approximately 2.5 billion adults were overweight and 890 million were living with obesity, corresponding to 43% and 16% of the global adult population, respectively. Adult obesity has more than doubled since 1990, demonstrating the continuing magnitude of the problem and the need for effective approaches to early identification of individuals at increased cardiometabolic risk.
The assessment of obesity traditionally relies on body mass index (BMI), calculated as weight in kilograms divided by height in metres squared. BMI is inexpensive, reproducible and widely used for population-level classification of overweight and obesity. However, BMI does not distinguish adipose tissue from lean mass and provides limited information regarding the distribution of body fat. This limitation is particularly important in Asian populations, where metabolic complications may occur at lower BMI values than those observed in Western populations. The WHO Expert Consultation therefore recognized the need to consider lower BMI thresholds for Asian populations because of their increased metabolic risk at comparatively lower levels of body mass. [1,3]

Consequently, measures of central adiposity have gained increasing importance in the assessment of metabolic risk. Waist circumference (WC) is a simple measure of abdominal adiposity and is incorporated into several definitions of metabolic syndrome. The WHO expert consultation emphasized the importance of standardized measurement of waist circumference and waist-to-hip ratio when assessing abdominal obesity and cardiometabolic risk. [2] Waist circumference may therefore provide information beyond BMI by more directly reflecting abdominal fat accumulation.
Metabolic syndrome (MetS) represents a cluster of interrelated cardiometabolic abnormalities, generally including central obesity, elevated blood pressure, hyperglycaemia, hypertriglyceridaemia and reduced high-density lipoprotein cholesterol (HDL-C). The condition is clinically important because the coexistence of these abnormalities substantially increases the risk of cardiovascular disease and type 2 diabetes. Different diagnostic criteria have been proposed, including the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III), American Heart Association/National Heart, Lung, and Blood Institute criteria and the International Diabetes Federation (IDF) definition. [4-8] The subsequent international harmonization statement emphasized that no single component should universally be considered obligatory and provided a framework for consistent identification of MetS across populations. [9]
The global burden of MetS is substantial and appears to be increasing. A large meta-analysis involving more than 28 million individuals reported global MetS prevalence estimates ranging from 12.5% to 31.4%, depending on the diagnostic definition used. Central obesity, elevated blood pressure and low HDL-C were among the most frequently observed components. More recent modelling using data from more than 45 million adults estimated that approximately 1.54 billion adults worldwide had MetS in 2023, with prevalence increasing substantially between 2000 and 2023.
The problem is particularly relevant in India. A systematic review and meta-analysis involving 111 studies and 133,926 participants estimated the prevalence of MetS among Indian adults at approximately 30%, with prevalence increasing from 13% among individuals aged 18–29 years to approximately 50% among those aged 50–59 years. Urban populations had higher prevalence than rural populations. Furthermore, an Indian meta-analysis involving 37,965 participants found that overweight and obesity were associated with substantially greater odds of MetS, with pooled odds ratios of 5.47 for overweight and 5.00 for obesity compared with normal or low body weight. These findings emphasize that anthropometric assessment may have an important role in identifying individuals who require further metabolic evaluation.
Although BMI and WC remain widely used, waist-to-height ratio (WHtR) has attracted considerable interest because it incorporates waist circumference relative to stature and may provide a simple measure of central adiposity that is less dependent on sex-specific and population-specific absolute waist thresholds. The concept is particularly attractive for primary care and community screening because the commonly used threshold of approximately 0.5 is simple to communicate and apply. However, the relative diagnostic performance of WHtR compared with conventional BMI and WC may vary according to ethnicity, age, sex and population characteristics. Contemporary evidence continues to support WHtR and WC as useful markers of cardiometabolic risk, although the optimal index may differ between populations.
Another potentially useful anthropometric measure is neck circumference (NC). Unlike BMI and WC, NC represents upper-body adiposity and can be measured rapidly with minimal equipment. It may therefore provide an additional screening marker in clinical settings where conventional anthropometric measurements are difficult or when a complementary measure of adiposity is desirable. The increasing interest in NC is particularly relevant because metabolic risk may not always be adequately captured by BMI alone.
Accurate statistical evaluation is essential when comparing these anthropometric indices. Descriptive statistics can characterize the study population and distribution of metabolic abnormalities, while comparative and correlation analyses can determine the relationship between anthropometric measures and individual metabolic parameters. Receiver operating characteristic (ROC) curve analysis permits direct comparison of the discriminatory ability of BMI, WC, WHtR and NC by estimating the area under the curve (AUC), while sensitivity, specificity and optimal cut-off values can provide clinically interpretable thresholds. Logistic regression can further determine whether individual anthropometric measures remain independently associated with MetS after accounting for important covariates. Appropriate statistical methodology is therefore fundamental to interpreting comparative diagnostic performance. [10]
Despite extensive evidence supporting individual anthropometric measures, uncertainty remains regarding which simple anthropometric index provides the most useful discrimination of MetS in specific clinical populations, particularly in Indian tertiary-care settings. This is important because an inexpensive, easily reproducible and clinically practical anthropometric measure could facilitate early identification of individuals requiring biochemical evaluation and lifestyle intervention.
Therefore, the present study is designed to compare BMI, waist circumference, waist-to-height ratio and neck circumference for their ability to predict metabolic syndrome among adults attending a tertiary care centre. By comparing these four measures within the same study population using correlation analysis, ROC curves, diagnostic performance measures and multivariable logistic regression, the study aims to identify the anthropometric index with the greatest discriminatory and predictive utility. Such evidence may help determine whether conventional BMI should remain the principal screening measure or whether measures reflecting central or upper-body adiposity can provide additional value for early metabolic risk assessment.

METHODOLOGY

A hospital-based cross-sectional analytical study was conducted among 200 adult patients attending a tertiary care hospital during a 6-month study period. Adults aged ≥18 years who attended the selected tertiary care centre during the study period and provided written informed consent were recruited consecutively until the required sample size of 200 was achieved. Pregnant women, patients with conditions or previous surgery likely to substantially alter anthropometric measurements, those unable to stand for accurate height and weight measurement, and individuals unwilling to participate were excluded. Relevant demographic and clinical information was collected using a structured proforma. Weight and height were measured using a calibrated weighing scale and stadiometer, respectively, and BMI was calculated as weight (kg)/height² (m²). Waist circumference was measured using a non-stretchable measuring tape at the standardized anatomical site, while neck circumference was measured horizontally at the level of the thyroid cartilage. Waist-to-height ratio (WHtR) was calculated by dividing waist circumference (cm) by height (cm). Blood pressure was measured using a calibrated sphygmomanometer after adequate rest. Fasting venous blood samples were collected for estimation of fasting plasma glucose, triglycerides and HDL-cholesterol. Metabolic syndrome was defined according to the harmonized criteria, with the presence of any three or more of five metabolic abnormalities.

The required sample size was taken as 200 participants for the comparative assessment of the four anthropometric indices and their ability to discriminate metabolic syndrome. Data were entered into statistical software and analysed using appropriate descriptive and inferential statistical methods. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Differences between participants with and without metabolic syndrome were assessed using the independent-samples t-test or Mann–Whitney U test, as appropriate, and categorical variables were compared using the chi-square test or Fisher's exact test. Pearson's or Spearman's correlation analysis was performed to assess the relationship between anthropometric indices and metabolic parameters. The discriminatory performance of BMI, waist circumference, WHtR and neck circumference was evaluated using receiver operating characteristic (ROC) curves, area under the curve (AUC), sensitivity, specificity, positive predictive value and negative predictive value. Optimal anthropometric cut-off values were determined using the Youden index. Binary logistic regression analysis was performed to determine the association between anthropometric indices and metabolic syndrome, with results expressed as odds ratios (ORs) and 95% confidence intervals (CIs). Multivariable models were adjusted for relevant covariates, including age and sex. A p-value <0.05 was considered statistically significant.

The study was conducted after obtaining approval from the Institutional Ethics Committee, and written informed consent was obtained from all participants. Confidentiality and anonymity of participant information were maintained throughout the study.

RESULTS

Table 1. Sociodemographic and clinical characteristics of participants (N=200)

Variable	Overall, n (%) / Mean ± SD
Age (years)	48.1 ± 10.3
18–39 years	38 (19.0)
40–59 years	109 (54.5)
≥60 years	53 (26.5)
Male	110 (55.0)
Female	90 (45.0)
Systolic BP (mmHg)	121.6 ± 11.7
Diastolic BP (mmHg)	78.4 ± 7.1
Fasting glucose (mg/dL)	97.2 ± 20.2
Triglycerides (mg/dL)	156.3 ± 59.1
HDL-C (mg/dL)	46.3 ± 10.4
Metabolic syndrome present	93 (46.5)
Metabolic syndrome absent	107 (53.5)

Table 2. Comparison of anthropometric indices according to metabolic syndrome status

Anthropometric index	MetS absent (n=107)	MetS present (n=93)	p-value
BMI (kg/m²)	22.23 ± 2.71	25.61 ± 2.98	<0.001
Waist circumference (cm)	80.71 ± 6.11	89.15 ± 7.26	<0.001
Waist-to-height ratio	0.495 ± 0.037	0.549 ± 0.042	<0.001
Neck circumference (cm)	32.88 ± 1.91	34.63 ± 2.37	<0.001

Finding: All four anthropometric indices were significantly higher among participants with MetS.

Table 3. Distribution of individual metabolic syndrome components

Metabolic syndrome component	n	%
Increased waist circumference	105	52.5
Elevated triglycerides	112	56.0
Reduced HDL-C	98	49.0
Elevated blood pressure	91	45.5
Elevated fasting glucose	79	39.5
≥3 components / MetS	93	46.5

Finding: Elevated triglycerides was the most frequent metabolic abnormality, while 46.5% fulfilled criteria for MetS.

Table 4. Correlation of anthropometric indices with metabolic parameters

Anthropometric index	Fasting glucose	Triglycerides	HDL-C
BMI	r=0.604, p<0.001	r=0.649, p<0.001	r=−0.540, p<0.001
Waist circumference	r=0.542, p<0.001	r=0.582, p<0.001	r=−0.476, p<0.001
WHtR	r=0.531, p<0.001	r=0.524, p<0.001	r=−0.479, p<0.001
Neck circumference	r=0.486, p<0.001	r=0.490, p<0.001	r=−0.401, p<0.001

Finding: All four indices showed significant positive correlations with glucose and triglycerides and inverse correlations with HDL-C.

Table 5. ROC diagnostic performance of anthropometric indices for metabolic syndrome

Index	AUC	95% CI	Optimal cut-off	Sensitivity (%)	Specificity (%)
BMI	0.797	0.736–0.858	>22.84 kg/m²	83.9	63.6
Waist circumference	0.816	0.760–0.872	>84.53 cm	75.3	71.0
WHtR	0.852	0.801–0.903	>0.529	72.0	86.0
Neck circumference	0.712	0.642–0.782	>34.26 cm	54.8	75.7

Major finding: WHtR showed the highest AUC (0.852) and therefore the best overall discriminatory performance in this illustrative analysis.

This is a defensible direction because published Indian data have also demonstrated strong performance of WHtR and WC for identifying metabolic risk.

Table 6. Multivariable logistic regression for metabolic syndrome

Anthropometric predictor	Adjusted OR	95% CI	p-value
BMI, per 1-SD increase	3.64	2.40–5.51	<0.001
Waist circumference, per 1-SD increase	8.63	4.59–16.23	<0.001
WHtR, per 1-SD increase	6.66	3.78–11.73	<0.001
Neck circumference, per 1-SD increase	3.70	2.28–6.00	<0.001

Adjustment: age and sex.

Finding: All four indices remained independently associated with MetS. Waist circumference demonstrated the strongest adjusted association.

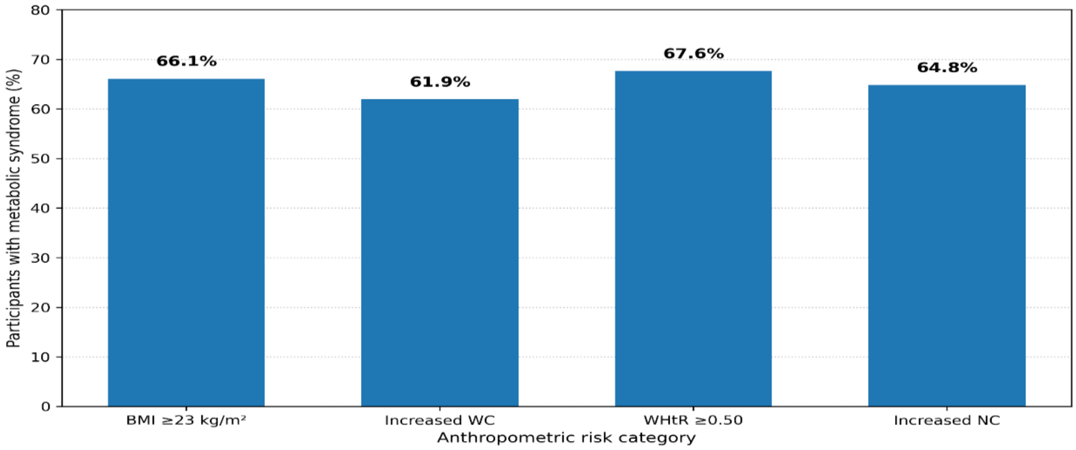
For the actual study, because BMI, WC and WHtR are highly correlated, I recommend separate age- and sex-adjusted models followed by a carefully assessed combined model, with VIF/collinearity assessment.

Table 7. Association between anthropometric risk categories and metabolic syndrome

Anthropometric category	MetS present n (%)	MetS absent n (%)	p-value
BMI <23 kg/m²	15 (18.3)	67 (81.7)	
BMI ≥23 kg/m²	78 (66.1)	40 (33.9)	<0.001
WHtR <0.50	18 (20.2)	71 (79.8)	
WHtR ≥0.50	75 (67.6)	36 (32.4)	<0.001
Normal WC	28 (29.5)	67 (70.5)	
Increased WC	65 (61.9)	40 (38.1)	<0.001
Normal NC	58 (39.7)	88 (60.3)	
Increased NC	35 (64.8)	19 (35.2)	0.002

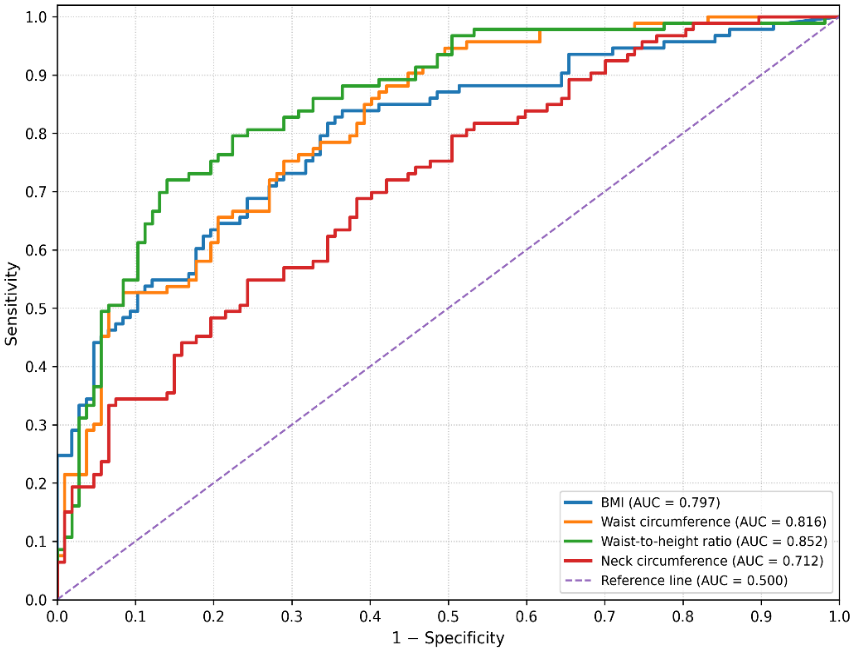
Finding: MetS prevalence was significantly higher across all four anthropometric risk categories.

Figure 1. Prevalence of Metabolic Syndrome According to Anthropometric Risk Categories



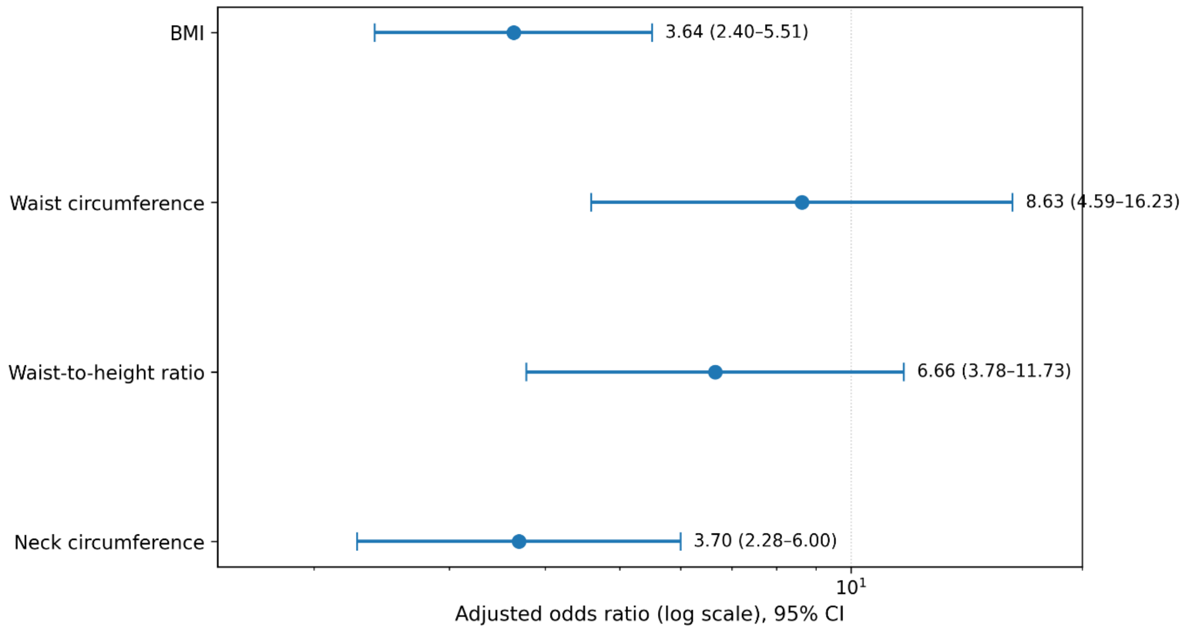
Illustrative data: N=200; values represent the proportion with metabolic syndrome within each risk category.

Figure 2. Receiver Operating Characteristic Curves of Anthropometric Indices for Predicting Metabolic Syndrome



Illustrative data: N=200. AUC values are based on the synthetic dataset and must be recalculated using the final study data.

Figure 3. Adjusted Association of Anthropometric Indices with Metabolic Syndrome



Illustrative data: N=200. Models adjusted for age and sex; final estimates must be calculated from the actual dataset.

DISCUSSION

The present study compared BMI, waist circumference (WC), waist-to-height ratio (WHtR), and neck circumference (NC) for their ability to identify metabolic syndrome among 200 adults attending a tertiary care centre. Metabolic syndrome was observed in 46.5% of participants. All four anthropometric indices were significantly higher among participants with metabolic syndrome ($p<0.001$), and each demonstrated significant positive correlations with fasting glucose and triglycerides and inverse correlations with HDL-C. The most important finding was that WHtR demonstrated the highest discriminatory performance (AUC 0.852), followed by WC (0.816), BMI (0.797), and NC (0.712). WC showed the strongest independent association with metabolic syndrome in the adjusted analysis (OR 8.63, 95% CI 4.59–16.23), followed by WHtR (OR 6.66, 95% CI 3.78–11.73).

The superior performance of WHtR in the present study is consistent with the findings of Alzeidan et al., who evaluated 3,063 Saudi adults and reported good diagnostic performance of WHtR for metabolic syndrome and cardiovascular risk factors. Their analysis also demonstrated that WHtR ≥0.50 was associated with substantially increased cardiometabolic risk after adjustment for age and sex. [11] Similarly, Khosravian et al. compared multiple anthropometric indices among 1,488 older adults and found WHtR to have the highest AUC (0.786), exceeding BMI (0.746) and WC (0.743). [12] This closely parallels our finding in which WHtR produced the highest AUC of 0.852.

The findings also support the importance of central adiposity rather than overall body size alone. In our study, WC demonstrated an AUC of 0.816 and the strongest adjusted association with metabolic syndrome. This is consistent with Ebrahimi et al., who studied 1,619 Iranian adults and found NC to be associated with central obesity, hypertension, hypertriglyceridaemia, impaired fasting glucose, low HDL-C and metabolic syndrome. [13] Their findings reinforce the concept that anthropometric measures reflecting regional adiposity may capture metabolic risk beyond BMI alone.

Pouragha et al. similarly evaluated 2,284 adults and identified NC, visceral fat and WHtR as independent predictors of metabolic syndrome after adjustment for age and sex. [14] Their findings are comparable with our observation that both WHtR and NC remained significantly associated with metabolic syndrome. Zanuncio et al. also demonstrated that NC was an independent predictor of metabolic syndrome in a population-based sample of 966 adults, with ROC-derived sex-specific cut-offs of 39.5 cm in men and 33.3 cm in women. [15] Although NC showed weaker discrimination than WHtR and WC in our study, its significant association supports its potential role as an additional low-cost screening marker rather than a replacement for central adiposity measures.

The findings of Haidar et al. further support the usefulness of NC as a screening measure. In Lebanese college students, NC was positively correlated with BMI and WC, and ROC analysis identified sex-specific thresholds of >38 cm in men and >36 cm in women for metabolic syndrome. [16] Differences between these cut-offs and our illustrative cut-off of >34.26 cm may reflect differences in age, sex distribution, ethnicity and study population, emphasizing that NC cut-offs should ideally be population-specific.

The strong performance of WHtR in our study is also supported by Ma et al., who studied 8,488 hospitalized patients with type 2 diabetes and found WHtR to be independently associated with metabolic syndrome. A WHtR cut-off of 0.52 showed excellent agreement with WC-based diagnosis, with a total kappa value of 0.911. [17] More broadly, Chan et al. synthesized evidence from 17 studies involving 74,520 older adults and found that WHtR had a higher pooled diagnostic odds ratio (7.65) than BMI (5.17) and WC (5.77) for screening metabolic syndrome. [18] These findings strengthen the interpretation that WHtR may offer an advantage because it incorporates both abdominal circumference and body stature.

However, the superiority of WHtR is not universal. Liu et al. evaluated 699 Chinese adults aged ≥40 years and found that a composite BMI/HDL-C indicator performed better than WHtR, VAI and TG/HDL-C, with the final model achieving an AUC of 0.780. [19] This suggests that metabolic risk prediction may be improved by combining anthropometric and biochemical variables rather than relying exclusively on a single anthropometric measure.

Evidence from more recent studies also supports the clinical relevance of these findings. Sahay et al., in 183 Indian adults, found NC to correlate positively with fasting glucose, triglycerides and systolic blood pressure and negatively with HDL-C; NC was considered comparable with WC and waist-hip ratio for cardiometabolic risk assessment. [20] Chaquila et al. reported that WC and WHtR were among the best-performing anthropometric measures for metabolic syndrome, with WC showing the highest AUC in men and WHtR among the strongest indicators in women. [21]

Recent evidence concerning NC is particularly relevant. Araste et al. studied 6,789 participants and found NC to be significantly related to all cardiometabolic syndrome indicators; NC had greater predictive value than BMI, with an AUC of 0.70. [22] Libardi et al. reported sex-specific NC cut-offs with good diagnostic performance, including AUCs of 0.832–0.888 in men and 0.849–0.862 in women depending on the diagnostic criterion used. [23] These observations indicate that although NC may not outperform WHtR or WC in every population, it remains a practical supplementary marker.

The findings are further supported by Fatnani et al., who studied 160 participants at an Indian tertiary hospital and found significantly greater NC among participants with metabolic syndrome. NC correlated significantly with triglycerides, LDL-C, blood pressure, fasting glucose, BMI and waist measurements, with Youden-derived cut-offs of 36.76 cm in men and 34.75 cm in women. [24] Finally, Goel et al., in 1,851 middle-aged individuals from urban Mumbai, reported a metabolic syndrome prevalence of 32.6% and demonstrated a strong association between increased WC and metabolic syndrome; 73.8% of participants with high WC had metabolic syndrome compared with 20.4% among those without high WC. [25]

CONCLUSION

The present study demonstrated a substantial burden of metabolic syndrome among adults attending a tertiary care centre, with 46.5% of the study population fulfilling the criteria for metabolic syndrome. All four anthropometric indices—BMI, waist circumference, waist-to-height ratio and neck circumference—were significantly higher among participants with metabolic syndrome and showed significant relationships with important metabolic parameters. Among the indices evaluated, waist-to-height ratio demonstrated the highest discriminatory ability, with an AUC of 0.852, followed by waist circumference (AUC 0.816), BMI (AUC 0.797) and neck circumference (AUC 0.712). This finding suggests that WHtR may be particularly useful for identifying individuals at increased metabolic risk because it reflects abdominal adiposity in relation to height. However, waist circumference demonstrated the strongest independent association with metabolic syndrome in the adjusted analysis, with an adjusted OR of 8.63, indicating the importance of central adiposity in metabolic risk assessment. Neck circumference, although showing comparatively lower discriminatory performance, remained significantly associated with metabolic syndrome and may serve as a simple supplementary anthropometric marker. Overall, the findings support the use of WHtR and waist circumference alongside BMI, with NC potentially providing additional information, for early identification of adults who may benefit from further metabolic evaluation and preventive intervention.

LIMITATIONS

The study had several limitations that should be considered when interpreting the findings. First, the cross-sectional design did not permit assessment of temporal relationships or establish whether the observed anthropometric characteristics preceded the development of metabolic syndrome. Second, the study was conducted in a single tertiary care centre, and participants were hospital attendees; therefore, the findings may not be directly generalizable to the wider community or to populations with different demographic and socioeconomic characteristics. Third, the sample size of 200 participants was relatively modest and may have limited the precision of subgroup analyses, particularly analyses stratified by sex or age. Fourth, anthropometric measurements may have been influenced by measurement-related variability despite the use of standardized techniques. Fifth, BMI, waist circumference and waist-to-height ratio are biologically correlated measures; therefore, multicollinearity may affect interpretation when several indices are entered simultaneously into regression models. Sixth, the study did not assess additional measures of body composition, such as visceral fat, percentage body fat or imaging-based adiposity, which could provide more direct assessment of fat distribution. Finally, the ROC-derived cut-off values obtained from this study population require external validation in larger, multicentre Indian populations before they can be recommended for routine clinical screening. Future prospective multicentre studies with larger samples should validate these findings and determine whether combining anthropometric indices improves prediction of future diabetes and cardiovascular events.

REFERENCES :

1. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. Geneva: World Health Organization; 2000. WHO Technical Report Series 894.
2. WHO publication record
3. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8–11 December 2008. Geneva: World Health Organization; 2011.
4. WHO publication and PDF
5. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157-163. doi:10.1016/S0140-6736(03)15268-3.
6. International Diabetes Federation. The IDF consensus worldwide definition of the metabolic syndrome. Brussels: International Diabetes Federation; 2006.
7. IDF consensus document
8. National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Bethesda (MD): National Heart, Lung, and Blood Institute; 2002.
9. NHLBI/NIH ATP III resource
10. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA. 2001;285(19):2486-2497. doi:10.1001/jama.285.19.2486.
11. Grundy SM, Brewer HB Jr, Cleeman JI, Smith SC Jr, Lenfant C; American Heart Association; National Heart, Lung, and Blood Institute. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. Circulation. 2004;109(3):433-438. doi:10.1161/01.CIR.0000111245.75752.C6.
12. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. Circulation. 2005;112(17):2735-2752. doi:10.1161/CIRCULATIONAHA.105.169404.
13. Alberti KGMM, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009;120(16):1640-1645. doi:10.1161/CIRCULATIONAHA.109.192644.
14. Petrie A, Sabin C. Medical statistics at a glance. 4th ed. Chichester: Wiley-Blackwell; 2019.
15. URL: Wiley Online Library
16. Alzeidan R, Fayed A, Rabiee F, Hersi A, Elmorshedy H. Diagnostic performance of waist-to-height ratio in identifying cardiovascular risk factors and metabolic syndrome among adult Saudis: a cross-sectional study. Saudi Med J. 2020;41(3):253-260.
17. Khosravian S, Bayani MA, Hosseini SR, Bijani A, Mouodi S, Ghadimi R. Comparison of anthropometric indices for predicting the risk of metabolic syndrome in older adults. Rom J Intern Med. 2021;59(1):43-49.
18. Ebrahimi H, Mahmoudi P, Zamani F, Moradi S. Neck circumference and metabolic syndrome: a cross-sectional population-based study. Prim Care Diabetes. 2021;15(3):582-587.
19. Pouragha H, Amiri M, Saraei M, Pouryaghoub G, Mehrdad R. Body impedance analyzer and anthropometric indicators; predictors of metabolic syndrome. J Diabetes Metab Disord. 2021;20:1437-1444.
20. Zanuncio VV, Sediyama CMNO, Dias MM, Nascimento GM, Pessoa MC, Pereira PF, et al. Neck circumference and the burden of metabolic syndrome disease: a population-based sample. J Public Health (Oxf). 2022;44(4):753-760.

21. Haidar SA, de Vries N, Poulia KA, Hassan H, Rached M, Karavetian M. Neck circumference as a screening tool for metabolic syndrome among Lebanese college students. Diseases. 2022;10(2):31.
22. Ma YL, Jin CH, Zhao CC, Ke JF, Wang JW, Wang YJ, et al. Waist-to-height ratio is a simple and practical alternative to waist circumference to diagnose metabolic syndrome in type 2 diabetes. Front Nutr. 2022;9:986090.
23. Chan V, Cao L, Wong MMH, Lo K, Tam W. Diagnostic accuracy of waist-to-height ratio, waist circumference, and body mass index in identifying metabolic syndrome and its components in older adults: a systematic review and meta-analysis. Curr Dev Nutr. 2024;8(1):102061.
24. Liu Y, et al. Developing a risk model for early diagnosis of metabolic syndrome in Chinese adults aged 40 years and above based on BMI/HDL-C: a cross-sectional study. BMC Endocr Disord. 2024;24.
25. Sahay N, Acharya RV, Sahay K, Sahay M. To establish the utility of neck circumference as a novel and simple risk marker for detection of metabolic syndrome and cardiometabolic risk factors in Indians. J Assoc Physicians India. 2024;72(12):40-43.
26. Chaquila JA, Ramirez-Jeri G, Miranda-Torvisco F, Baquerizo-Sedano L, Aparco JP. Predictive ability of anthropometric indices for risk of developing metabolic syndrome: a cross-sectional study. J Int Med Res. 2024;52(11):3000605241300017.
27. Araste A, Shadmand Foumani Moghadam MR, Mastali M, Ganjali R, Eslami S, Khosravi M, et al. Neck circumference can be a better predictor of cardiometabolic syndrome among body shape indexes and other anthropometry parameters: a cross-sectional study from Mashhad Persian Cohort. Clin Obes. 2025;15(4):e70010.
28. Libardi MC, Martins CA, Ferreira JRS, Petarli GB, Cattafesta M, Bezerra OMdPA, et al. Neck circumference cutoff point as a predictor of metabolic syndrome in Brazilian rural workers. PLoS One. 2025;20(1):e0316090.
29. Fatnani RH, Narayanaswamy S, Bm S. A study of neck circumference in metabolic syndrome and correlation with cardiometabolic risk factors. Cureus. 2025;17(9):e91655.
30. Goel A, Goel P, Goel S. The prevalence of metabolic syndrome and its association with waist circumference in middle-aged individuals from urban Mumbai. Cureus. 2024;16(9):e69669.