

Original Research Article

Beyond BMI: association of body roundness, abdominal volume, conicity and body shape indices with insulin resistance and metabolic risk in urban Indian adolescents and adults

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ABSTRACT

Background: Body roundness index (BRI), Abdominal volume index (AVI), Conicity index (CI), and a body shape index (ABSI) have been proposed as improved predictors of adiposity and metabolic risk. This study evaluated gender differences, age-related trends, diagnostic performance and associations of these indices with adiposity and metabolic parameters.

Methods: A cross-sectional analysis was conducted among 1,998 apparently healthy Indian adolescents and adults (620 males and 1,378 females; 16–55 years) from the Mumbai Metropolitan Region. Anthropometric measurements, body composition, and biochemical parameters were assessed. BRI, AVI, CI, and ABSI were calculated. Gender differences were compared using independent t-tests, age-related trends across quintiles, receiver operating characteristic analysis assessed diagnostic accuracy, and Pearson's correlation examined associations with metabolic parameters.

Results: Adiposity indices increased significantly with age, whereas muscle mass declined ($p < 0.001$). Females had higher BMI, waist-to-height ratio, body fat percentage, and BRI, while males had higher waist circumference, waist-to-hip ratio, visceral fat, muscle mass, AVI, CI, and ABSI (all $p < 0.01$). BRI showed the highest accuracy for identifying obesity (AUC=0.953) and central obesity (AUC=1.000), followed by AVI. Both BRI and AVI correlated with adiposity measures, fasting glucose, fasting insulin, HbA1c, and HOMA-IR (all $p < 0.001$). AVI was independently associated with HOMA-IR and fasting insulin, whereas BRI was associated with the fasting glucose-to-insulin ratio.

Conclusion: BRI and AVI are reliable, low-cost markers of adiposity and early metabolic dysfunction. BRI showed superior diagnostic accuracy for obesity, whereas AVI demonstrated stronger associations with insulin resistance, supporting their use in early cardiometabolic risk screening among apparently healthy Indian populations.

Keywords: Body roundness index, Conicity index, A body shape index, Abdominal volume index, Urban Indian adults, Insulin resistance

INTRODUCTION

The global prevalence of obesity is a growing concern. It is no more a problem of high-income countries but is on the rise in low- and middle-income countries. In 2024, the NCD Risk Factor Collaboration (NCD-RisC) published estimate that more than one billion people (nearly 880 million adults and 159 million children and adolescents aged 5-19 years) in the world are now living with obesity.¹ Obesity can alter the metabolic health of people, increase risk of type 2 diabetes and heart disease as well as PCOS and other metabolic syndromes (MetS).²⁻⁴ MetS is a significant community health concern and in India it is estimated to be around 25% to 30%.^{5,6} Abdominal (visceral) obesity (AO) is the most predominant component of MetS and serves as a dysfunctional adipose tissue marker which is connected with systemic inflammation, dyslipidemia, insulin resistance and CVD.⁷⁻¹³

Traditionally, Body Mass Index (BMI) has been widely used to classify obesity; however, it does not account for fat distribution or distinguish between fat mass and lean mass. Measures of central adiposity such as waist circumference (WC), waist-hip ratio (WHR), and waist-to-height ratio (WHtR) have therefore been increasingly recognized as better indicators of metabolic risk.¹⁴ This indicates that the distribution of fat is critical along with the amount of fat. In recent years, novel anthropometric indices including, Body Roundness Index (BRI), Abdominal Volume Index (AVI), Conicity Index (CI), and A Body Shape Index (ABSI) have been developed to provide a more comprehensive assessment of body fat distribution and associated health risks.^{15-19,20} These indices integrate multiple anthropometric parameters and are proposed to better reflect visceral adiposity and cardiometabolic risk compared to conventional measures. Emerging evidence suggests that indices such as BRI and AVI may have superior predictive ability for obesity and metabolic abnormalities, although findings remain inconsistent across populations.

Sex and age are important determinants of body composition and fat distribution. Males and females differ significantly in fat accumulation patterns, while ageing is associated with increased adiposity and reduced muscle mass. Understanding how novel indices behave across gender and age groups is essential for their effective application in clinical and public health settings. Furthermore, the relationship of these indices with metabolic biomarkers such as fasting glucose, insulin, glycated hemoglobin (HbA1c), and insulin resistance markers (HOMA-IR) needs to be explored. Establishing strong correlations would support their use as simple, non-invasive screening tools for early identification of individuals at risk.

Very few studies have been conducted on the Indian population in relation to these indices. With the increasing burden of obesity, particularly in young and

middle-aged population, it was deemed worthwhile to explore these novel anthropometric indices for its potential utility in Indian population. Therefore, the present study aimed to evaluate gender differences, age-wise variations, diagnostic performance, and correlations of BRI, AVI, CI, and ABSI with conventional anthropometric and metabolic parameters in urban Indian adolescents and adults.

METHODS

Study design and sample selection

The present cross-sectional analysis utilized data pooled from two cross-sectional studies conducted between 2018 and 2024 in the Mumbai Metropolitan Region. A total of 1,998 apparently healthy adolescents and adults were screened as part of two clinical studies. Both studies were designed to evaluate anthropometric characteristics and cardiometabolic risk factors using similar recruitment strategies and standardized protocols for data collection. Participants were recruited from academic institutions, government organizations, and corporate workplaces. Eligible participants were apparently healthy individuals aged 16–55 years. Individuals with known chronic diseases, those receiving medications that could influence metabolic parameters (e.g., corticosteroids) and pregnant or lactating women were excluded from the study.

Ethical considerations

The studies were approved by the Intersystem Biomedical Ethics Committee, Mumbai, India (ISBEC version 2 dated 12th Aug, 2017 & ISBEC, 21st October, 2022) and were conducted according to Good Clinical Practices and the Declaration of Helsinki. Informed written consent was taken from each adult participant and each guardian/parent for participants who were between 16 and 18 years of age.

Measurements

Each participant first underwent a clinical examination by a physician to assess the general health status. Body composition was measured using the TANITA body composition analyser (Model MC 780 MA). Each measurement was taken thrice and the average was calculated.

Participants were weighed using a calibrated digital weighing scale (Equinox, Model EB6171, accuracy 0.1kg). It was ensured that they were wearing light clothing and no footwear at the time of measurement. The scale was zeroed before every measurement. Height was measured using a stadiometer (accuracy of 0.1cm). Subjects were asked to remove their footwear, stand with their feet together, knees straight and chin parallel to the ground. Care was taken that the back of the head (occipital lobe), shoulder blades, buttocks and heels were in contact with the stadiometer vertical surface. Body

Mass Index (BMI) was calculated as weight/height² (kg/m²) and participants were classified as underweight, normal, overweight or obese based on the WHO criteria for Asians (2004).²¹

Waist circumference (WC) and hip circumference (HC) were measured with a calibrated, non-extensible, flexible measuring tape to its nearest 0.1 cm. WC was measured at a level midway between the bottom of the rib cage and superior margin of iliac crests during inspiration and hip circumference at the maximal diameter of the buttocks. Waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) was calculated. WHtR ≥ 0.50 was considered as the optimal cut-off.²²

Based on height, weight, WC, and HC, we calculated the following novel anthropometric indices.

Body Roundness Index: BRI was calculated according to the formula developed by Thomas et al.²³

$$BRI = 364.2 - 365.5 \times \sqrt{1 - \frac{(\frac{\text{waist circumference (in cm)}}{2\pi})^2}{(0.5 \times \text{height in centimetres})^2}}$$

A body shape index

ABSI provides a better representation of abdominal fat distribution, which is more strongly linked to conditions like cardiovascular disease and type 2 diabetes.²⁴

The formula for ABSI = $\frac{\text{Waist Circumference}}{(\text{BMI}^{2/3} \times \text{Height}^{1/2})}$ where, waist circumference (WC) and height are in meters, and Body Mass Index (BMI) is in kg/m². A higher ABSI indicates a larger waist circumference relative to BMI, indicating higher visceral fat and increased mortality risk

Conicity index

The conicity index (CI) measures abdominal obesity based on body shape, specifically how closely a person's shape resembles a double cone (>1.0) rather than a cylinder (1.0). The conicity index (CI) is calculated using the following formula:²⁵

$$CI = \frac{\text{Waist Circumference (m)}}{[0.109 \times \sqrt{\frac{\text{Body Weight (kg)}}{\text{Height (m)}}}]}$$

1.0: Represents a perfect cylinder (no specific abdominal fat distribution).

>1.0: Represents a biconic shape, indicating greater central/abdominal fat accumulation.

<1.0: Represents a biconcave shape.

Therefore, higher values indicate increased central adiposity.

Abdominal volume index

The AVI is calculated using waist circumference (WC) and hip circumference (HC) measurements. A common formula is:²⁶

$$AVI = \frac{(2 \times \text{waist circumference})^2 + 0.7 \times (\text{WC} - \text{HC})^2}{1000}$$

Where, WC and HC are in cm.

Biological samples, collection, storage and biochemical measurements

Blood samples of the participants were collected after an overnight fast of at least 12 hours. Venous blood (10 ml) was collected in fasting state. Two ml of fasting blood sample was immediately transferred to a BD vacutainer (spray-coated K2EDTA Tubes) for complete blood count (CBC) and HbA1c, two ml of fasting blood sample was immediately transferred to a BD vacutainer (spray-coated sodium fluoride tubes) for estimation of plasma glucose levels and insulin. The remaining fasting serum was divided into aliquots and stored at -70°C until further analyses.

CBC was done for all participants. Along with CBC, the following measurements were done: glucose was measured by the GOD POD method (Accurex Biomedical Pvt Ltd), insulin was measured by radioimmunoassay using a Beckman Coulter Counter. HbA1c was measured using Nycocard reader (Alere Technologies, Norway). Hemoglobin A1c (HbA1c) was measured by high-performance liquid chromatography (HPLC). Insulin resistance was calculated by HOMA-IR using the formula:²⁷

$$HOMA\ IR = \frac{\text{Fasting Glucose (mg/dl)} \times \text{Fasting Insulin (microIU/ml)}}{405}$$

Statistical analysis

Statistical analyses were performed using SPSS software version 27.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were summarized as frequencies and percentages. Normality of distribution was assessed using the Kolmogorov–Smirnov test prior to applying parametric tests. Comparisons between males and females were performed using the independent sample student's t-test for continuous variables. One-way analysis of variance (ANOVA) was used to compare anthropometric indices across different age quintiles. Pearson's correlation analysis assessed associations between adiposity indices and metabolic parameters, while receiver operating characteristic (ROC) analysis evaluated their ability to identify obesity, central obesity, and insulin resistance. Multivariable linear regression was performed to determine the independent associations of adiposity indices with metabolic risk markers. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 1,998 participants (males: n=620; females: n=1,378) were included in the analysis. As shown in Table 1, females were significantly older than males (27.2±11.6 vs 25.1±11.0 years, $p<0.001$). Males had significantly higher weight, waist circumference (WC), waist-hip ratio (WHR), visceral fat, and muscle mass

($p<0.01$ for all), whereas females had significantly higher BMI, waist-to-height ratio (WHtR), and percentage body fat ($p<0.01$). Among the novel indices, females exhibited higher Body Roundness Index (BRI) (3.07 ± 1.45 vs 2.87 ± 1.46 , $p=0.006$), while males had higher Conicity Index (CI), Abdominal Volume Index (AVI), and Body Shape Index (ABSI) ($p<0.001$ for all) (Table 1).

Table 1: Comparison of BRI, CI, ABSI and AVI in males and females.

	Gender Mean (SD), Median		t, p-value
	Male (n=620)	Female (n=1378)	
Age (years)	25.1 (11.0) 19.0	27.2 (11.6) 21.0	-3.839, 0.000
Weight (kg)	65.4 (15.1) 63.0	57.8 (13.5) 56.0	-3.170, 0.002
BMI (kg/m ²)	23.1 (4.9) 22.6	23.9 (5.4) 23.3	7.073, 0.000
WC (cm)	78.5 (12.9) 77.0	74.4 (11.8) 73.0	7.073, 0.000
WHR	0.84 (0.06) 0.83	0.78 (0.07) 0.78	19.378, 0.000
WHtR	0.47 (0.08) 0.46	0.48 (0.08) 0.47	-3.205, 0.001
% Body fat	20.6 (7.5) 20.0	32.7 (7.1) 33.0	-34.584, 0.000
Visceral fat	7.25 (5.55) 7.00	5.84 (4.74) 5.00	5.533, 0.000
Muscle mass	42.3 (10.3) 44.0	29.8 (7.0) 30.0	30.136, 0.000
Body roundness index	2.87 (1.46) 2.58	3.07 (1.45) 2.81	-2.778, 0.006
Conicity index	1.15 (0.11) 1.15	1.12 (1.0) 1.12	6.590, 0.000
Abdominal volume index	12.79 (4.30) 11.98	11.66 (3.69) 11.03	6.026, 0.000
Body Shape Index	0.76 (0.06)	0.74 (0.07)	8.193, 0.000

$p<0.05$ was statistically significant

Table 2: Mean anthropometric measurements and novel indices of adiposity within age quintiles.

	Age					P value
	Q1 (15-18 yrs) (n=446)	Q2 (19-20 yrs) (n=495)	Q3 (21-22 yrs) (n=324)	Q4 (23-39 yrs) (n=351)	Q5 (40-55 yrs) (n=382)	
Weight (kg)	54.3 (11.6)	56.0 (12.9)	59.3 (14.8)	64.2 (13.5)	69.6 (14.3)	0.000
BMI (kg/m ²)	21.0 (4.1)	21.9 (4.6)	23.5 (5.4)	25.1 (4.6)	27.6 (4.8)	0.000
WC	69.9 (9.6)	71.2 (10.1)	73.5 (11.6)	79.5 (11.5)	86.6 (10.7)	0.000
WHR	0.79 (0.06)	0.78 (0.06)	0.77 (0.06)	0.81 (0.07)	0.84 (0.09)	0.000
WHtR	0.43 (0.06)	0.45 (0.06)	0.46 (0.07)	0.50 (0.07)	0.54 (0.07)	0.000
% Body Fat	22.8 (8.7)	26.2 (8.6)	30.2 (8.6)	31.6 (6.6)	36.2 (6.1)	0.000
Visceral Fat	3.3 (2.8)	3.9 (3.0)	5.1 (3.9)	7.6 (4.8)	11.5 (5.3)	0.000
Muscle Mass	38.6 (7.6)	38.7 (8.4)	35.9 (9.3)	29.6 (9.1)	23.8 (3.6)	0.000
Body Roundness Index	2.30 (1.08)	2.49 (1.10)	2.79 (1.38)	3.43 (1.36)	4.31 (1.44)	0.000
Conicity Index	1.11 (0.07)	1.11 (0.07)	1.10 (1.0)	1.15 (0.11)	1.19 (0.14)	0.000
Abdominal Volume Index	10.2 (2.9)	10.6 (3.0)	11.4 (3.7)	13.2 (3.7)	15.3 (4.0)	0.000
Body Shape Index	0.74 (0.05)	0.74 (0.04)	0.73 (0.06)	0.75 (0.07)	0.77 (0.10)	0.000

Age-wise trends (Table 2) revealed a significant progressive increase in weight, BMI, WC, WHtR, body fat percentage, visceral fat, BRI, CI, AVI, and ABSI across age quintiles ($p<0.001$). Conversely, muscle mass showed a declining trend with increasing age ($p<0.001$). The highest values for adiposity indices were observed in the oldest age group (40–55 years), indicating an age-associated increase in central and overall adiposity (Table 2).

Table 3 presents the diagnostic performance of novel anthropometric indices. ROC analysis revealed that BRI demonstrated the highest predictive ability for obesity (AUC=0.953) and central obesity (AUC=1.000), followed by AVI (AUC=0.944 and 0.973, respectively). BRI

showed high sensitivity and specificity for identifying obesity (94.1% and 80.1%) at a cut-off of 2.84, while a cut-off of 3.35 provided perfect discrimination for central obesity. CI exhibited moderate diagnostic performance, whereas ABSI had poor discriminatory ability. These findings indicate that BRI and AVI are superior indices for identifying adiposity-related risk in this population.

Correlation analysis (Table 4) showed that BRI and AVI had strong positive correlations with BMI ($r=0.875$ and $r=0.848$, respectively), WHtR ($r=0.983$ and $r=0.927$), and visceral fat ($r=0.845$ and $r=0.872$) ($p<0.001$ for all). CI demonstrated moderate correlations with WHR ($r=0.787$) and WHtR ($r=0.749$). ABSI showed weaker correlations with most anthropometric and metabolic parameters.

Table 3: Sensitivity and specificity of novel anthropometric indices in identifying overweight and obesity.

	BRI	AVI	CI	ABSI
AUC for predicting obesity by BMI				
AUC	0.953	0.944	0.733	0.522
Sensitivity	94.1%	92.2%	79.8%	40.0%
Specificity	80.1%	80.3%	50.6%	66.0%
Cut Off	2.84	11.7	1.10	0.76
AUC for predicting central obesity by WHtR				
AUC	1.000	0.973	0.859	0.671
Sensitivity	100%	98.0	82.3%	50.0%
Specificity	100%	80.0%	70.3%	23.2%
Cut Off	3.35	11.53	1.13	0.77

Table 4: Correlation of body roundness index, conicity index body shape index and abdominal volume index with anthropometry measurements.

	Body roundness index	Conicity index	Abdominal volume index	Body shape index
	R	P value	R	P value
BMI	0.875**	0.336**	0.848**	-0.045*
	0.000	0.000	0.000	0.047
WHR	0.578**	0.787**	0.626**	0.645**
	0.000	0.000	0.000	0.000
WHtR	0.983**	0.749**	0.927**	0.397**
	0.000	0.000	0.000	0.000
% Body fat	0.671**	0.222**	0.553**	-0.068**
	0.000	0.000	0.000	0.002
Visceral fat	0.845**	0.470**	0.872**	0.139**
	0.000	0.000	0.000	0.000
Muscle mass	-0.227**	-0.088**	-0.065**	-0.040
	0.000	0.000	0.005	0.087
WBC	0.256**	0.136**	0.215**	0.025
	0.000	0.000	0.000	0.335
Fasting sugar	0.226**	0.143**	0.224**	0.055*
	0.000	0.000	0.000	0.030
Fasting insulin	0.322**	0.173**	0.314**	0.027
	0.000	0.000	0.000	0.295
HbA1c	0.280**	0.206**	0.256**	0.140**
	0.001	0.000	0.000	0.000

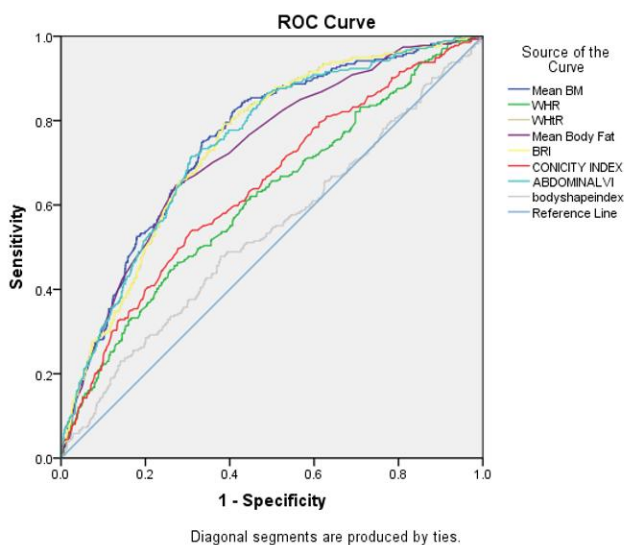
Continued.

	Body roundness index	Conicity index	Abdominal volume index	Body shape index
	R	P value	R	P value
HOMA IR	0.331**	0.182**	0.326**	0.034
	0.000	0.000	0.000	0.179
FG/FI Ratio	-0.269**	-0.142**	-0.256**	-0.013
	0.000	0.000	0.000	0.611

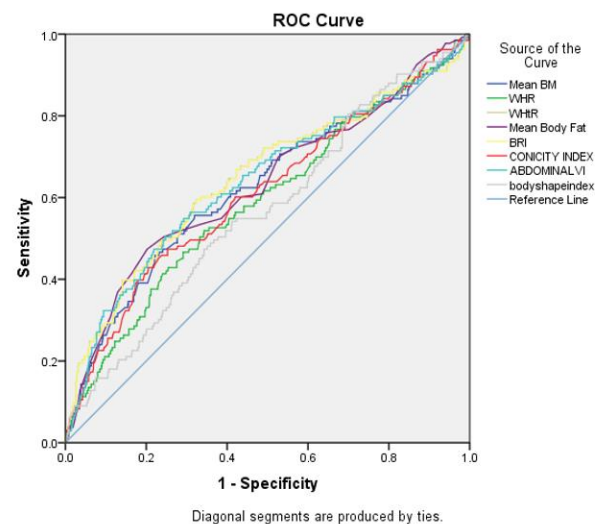
r= Pearson's coefficient value; **p<0.05 showed a significant correlation

BRI and AVI were positively correlated with fasting glucose, insulin, HbA1c, and HOMA-IR ($p<0.001$), and negatively correlated with FG/FI ratio (Table 4). Muscle mass was negatively correlated with all indices except ABSI, where the association was not significant. Overall, BRI and AVI emerged as the strongest correlates of both anthropometric and metabolic risk markers.

Receiver operating characteristic (ROC) curves were plotted for BRI, CI, AVI and ABSI with HOMA IR and HbA1c (Figure 1). The ROC analysis showed that BRI (AUC=0.746) and BMI (AUC=0.746) had highest AUC to predict HOMA IR followed by AVI (AUC=0.744). The AUC was highest for BRI (AUC=0.648) and WHtR (AUC=0.647) to predict HbA1c followed by AVI (AUC=0.639) (Figure 1).



HOMA IR



HbA1c

Figure 1: ROC curve for HOMA IR, HbA1c and anthropometry indices.

In multivariable linear regression analysis adjusted for age, sex, BMI, body fat percentage, and muscle mass, AVI independently and significantly associated with HOMA-IR ($\beta=0.282$, $p=0.021$) and fasting insulin ($\beta=0.244$, $p=0.045$). BRI was the only novel anthropometric index independently associated with FG/FI ratio ($\beta=0.308$, $p=0.034$) whereas, BRI and AVI were independently and positively associated with HbA1c levels. Overall, these findings suggest that AVI appears to be a stronger independent marker of insulin resistance and hyperinsulinemia, while BRI shows a stronger association with long-term glycemic status (HbA1c) and FG/FI ratio.

DISCUSSION

The present study evaluated the utility of novel anthropometric indices, namely Body Roundness Index (BRI), Abdominal Volume Index (AVI), Conicity Index

(CI), and A Body Shape Index (ABSI), in assessing adiposity, insulin resistance, and metabolic risk among Indian adolescents and adults. The findings demonstrate that BRI and AVI were superior to CI and ABSI in identifying general and central obesity and showed stronger associations with metabolic risk markers. Importantly, after adjustment for age, sex, BMI, body fat percentage, and muscle mass, AVI remained independently associated with fasting insulin and HOMA-IR, whereas BRI showed independent associations with HbA1c and FG/FI ratio.

Significant sex-related differences in anthropometric characteristics were observed. Males had higher weight, waist circumference, WHR, visceral fat, and muscle mass, whereas females exhibited higher BMI, WHtR, body fat percentage, and BRI. These findings are consistent with established sex-specific differences in body composition, where females generally possess

higher total body fat, while males have greater lean mass and more central fat accumulation.²⁷ The higher BRI values observed among females may reflect the influence of increased body fat and body shape characteristics captured by this index.

An age-dependent increase in adiposity was observed, with progressive increases in BMI, waist circumference, WHtR, visceral fat, and all novel adiposity indices across age groups, accompanied by a decline in muscle mass. These findings indicate a shift toward increased adiposity and reduced lean mass with advancing age, which may contribute to deterioration in metabolic health. The marked increase in BRI and AVI among older participants suggests that these indices effectively capture age-related changes in body fat distribution, particularly abdominal adiposity and underscores the increasing cardiometabolic risk in older adults. Aging alters adipose tissue composition and function resulting in insulin resistance and ectopic lipid storage.²⁸

Correlation analysis provided additional insights into the clinical relevance of these indices. BRI and AVI showed strong positive correlations with BMI, WHtR, and visceral fat, indicating that they effectively capture both overall and central adiposity. Moreover, their significant associations with fasting glucose, insulin, HbA1c, and HOMA-IR suggest that these indices are closely linked to metabolic dysfunction and insulin resistance. The negative correlation with the fasting glucose-to-insulin ratio further supports their relevance in identifying impaired metabolic states. CI demonstrated moderate correlations with central obesity measures, while ABSI showed weak and inconsistent associations with both anthropometric and metabolic parameters, limiting its clinical applicability in this population.

The ROC analysis demonstrated excellent discriminatory ability of BRI and AVI for identifying obesity and central obesity. BRI showed the highest accuracy for obesity classification, with high sensitivity and specificity, while AVI showed similarly strong performance. The superior performance of BRI and AVI may be explained by their incorporation of waist circumference, a measure that reflects abdominal fat accumulation and is more closely associated with cardiometabolic risk than body weight alone. The perfect discrimination observed for BRI in identifying central obesity defined by WHtR should be interpreted with caution, as both BRI and WHtR are derived from waist circumference and height and therefore share a mathematical relationship.

Although BRI demonstrated the strongest correlations and ROC performance in unadjusted analyses, multivariable regression analysis revealed that AVI was the only novel anthropometric index independently associated with fasting insulin and HOMA-IR after accounting for age, sex, BMI, body fat percentage, and muscle mass. This finding suggests that AVI may better

reflect abdominal adiposity linked to insulin resistance beyond traditional measures of body composition. Conversely, BRI remained independently associated with HbA1c and FG/FI ratio, indicating its potential role as an indicator of long-term glycemic status.

The present findings have important clinical implications, particularly for populations such as Indians who have a greater propensity for central adiposity and metabolic abnormalities even at relatively lower BMI values.²⁷ Simple anthropometric indices capable of identifying individuals at increased metabolic risk are valuable for large-scale screening and early prevention strategies. The findings suggest that AVI may be particularly useful for identifying insulin resistance, while BRI may serve as an effective marker for overall adiposity and glycemic abnormalities.

The strengths of this study include the large sample size, inclusion of both adolescents and adults, assessment of multiple novel anthropometric indices, and comprehensive evaluation of anthropometric, body composition, and metabolic parameters. However, certain limitations should be acknowledged. The cross-sectional design limits causal inference, and longitudinal studies are required to establish the predictive ability of these indices for future diabetes and cardiometabolic outcomes. Additionally, the strong correlations among BMI, BRI, and AVI may introduce multicollinearity in regression models, and future studies may explore separate models or advanced statistical approaches to evaluate their independent predictive value.

CONCLUSION

In conclusion, BRI and AVI showed superior performance over CI and ABSI in identifying adiposity and metabolic risk among Indian adolescents and adults. While BRI exhibited excellent discriminatory ability for obesity and was associated with glycemic markers, AVI emerged as the strongest independent predictor of insulin resistance and fasting insulin. These findings support the use of BRI and AVI as simple, low-cost tools for early identification of individuals at increased cardiometabolic risk.

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