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Comparison of Waist-Height Ratio and Waist-Hip Ratio as Markers of Central Obesity in School-Going Children Aged 11 to 15 Years: A Cross-Sectional Study

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Abstract

Background: Childhood obesity is a growing public health concern, and excess abdominal (central) adiposity carries cardiometabolic risk independent of overall body mass index (BMI). Asian Indian children develop metabolic complications at lower BMI thresholds than Western populations, making simple anthropometric markers of central adiposity attractive for school-based screening. This study compared waist-height ratio (WHtR) and waist-hip ratio (WHR) as markers of central obesity in early adolescence.

Materials and Methods: A cross-sectional observational study was conducted among 824 children aged 11–15 years in private urban schools of Bengaluru. After parental consent and child assent, weight, height, waist circumference, and hip circumference were measured using calibrated instruments. WHtR (waist circumference/height) and WHR (waist circumference/hip circumference) were calculated and correlated with BMI. Receiver operating characteristic (ROC) curve analysis evaluated the diagnostic performance of both indices for overweight and central obesity, defined using WHO BMI-for-age percentiles.

Results: The mean age was 13.05±1.42 years (53.3% male). Overweight and central obesity were present in 15.2% (n=125) and 3.5% (n=29) of children, respectively. Mean WHR was 0.89±0.05 and mean WHtR was 0.44±0.05. WHR correlated weakly with BMI (r=0.235, $p<0.001$), whereas WHtR correlated strongly (r=0.725, $p<0.001$). WHtR varied significantly with age (p=0.003) and was markedly higher in children with acanthosis nigricans (0.52 vs 0.43, $p<0.001$), while

WHR showed neither association. On ROC analysis, WHtR outperformed WHR for detecting overweight (AUC 0.891 vs 0.650) and central obesity (AUC 0.903 vs 0.642), with a WHtR cut-off of >0.48 yielding 86.2% sensitivity and 85.0% specificity for central obesity.

Conclusion: WHtR demonstrated a stronger correlation with BMI and substantially superior diagnostic accuracy than WHR for identifying overweight and central obesity in children aged 11–15 years. WHtR is a simple, reproducible, and clinically useful tool for school-based screening of central adiposity in this age group.

Keywords: Childhood Obesity, Waist-Height Ratio, Waist-Hip Ratio, Central Obesity, Body Mass Index, Anthropometry, Adolescents, School Children

Introduction

Paediatric obesity is now recognised as a chronic disease characterised by excess or dysfunctional body fat that impairs health and leads to long-term morbidity and early mortality [1]. Once considered a problem of high-income nations, it has reached epidemic proportions even in middle- and low-income countries, including urban and rural India [1]. Globally, the prevalence of overweight among children and adolescents aged 5–19 years rose from 8% in 1990 to 20% in 2022, and obesity now affects an estimated 160 million young people worldwide [2].

In India, nearly 26 million children aged 10–19 years are estimated to be overweight or obese, with the country ranking second globally in absolute disease burden attributable to high BMI [2]. Childhood obesity tracks into adulthood and predisposes to long-term cardiovascular and metabolic consequences, including hyperlipidaemia, coronary heart disease, and type 2 diabetes mellitus [3]. Excess fat accumulated specifically in the abdominal region — central obesity — elevates cardiovascular risk independent of overall adiposity [3].

Body mass index (BMI) remains the standard clinical measure of overweight, but it cannot distinguish fat from lean mass and does not capture the distribution of body fat[3]. This is a particular limitation in Asian Indian children, who, for any given BMI, carry a higher proportion of adipose tissue, more abdominal fat, and lower muscle mass than white Caucasian children, predisposing them to insulin resistance and type 2 diabetes mellitus even within a BMI range considered normal[4]. Waist-based indices such as waist-hip ratio (WHR) and waist-height ratio (WHtR) have therefore been proposed as simple, low-cost alternatives that more directly reflect central fat distribution [3], [4].

WHtR in particular has gained attention because it is age- and sex-independent across a wide range of childhood ages, unlike waist circumference percentiles, which require separate age- and sex-specific reference charts[3]. Comparative data on the relative diagnostic performance of WHtR and WHR for detecting central obesity in Indian school-going children, however, remain limited. With childhood obesity prevalence continuing to rise in urban India, identifying a simple and reliable anthropometric screening tool that can be deployed in school health programmes is of considerable public health importance [5].

This study was therefore undertaken to determine the WHR and WHtR of school-going children aged 11 to 15 years, to correlate these anthropometric indices with BMI, and to compare which of the two parameters more accurately identifies central obesity in this age group.

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Materials And Methods

Study Design and Setting

This was a cross-sectional observational study conducted in private urban schools of Bengaluru, Karnataka, over a period of 18 months (July 2024 to January 2026), after obtaining institutional ethical committee clearance and administrative permission from participating school managements.

Study Population

School-going children aged 11 to 15 years, of either gender, studying in the middle and secondary classes of selected private urban schools, were eligible. Children with known chronic medical conditions (hypothyroidism, nephrotic syndrome, growth disorders) or on long-term medications affecting body composition or growth (corticosteroids, anticonvulsants, estrogen therapy) were excluded, as were children whose parents or guardians did not provide written informed consent, or who themselves declined assent.

Sample Size

The sample size was calculated using the standard formula for prevalence studies ($n = Z^2 \cdot P \cdot Q/d^2$), assuming a childhood obesity prevalence of 8.4% reported by a national meta-analysis [8], with 95% confidence and 2% absolute precision. The calculated sample size of 811 was rounded up to 824 for operational feasibility.

Procedure

Written informed consent was obtained from parents/guardians, and assent was obtained from children aged 12 years and above. Weight was measured to the nearest 0.1 kg using an electronic scale, and height to the nearest 0.1 cm using a stadiometer with the head in the Frankfurt horizontal plane. Waist circumference was measured at the midpoint between the lower costal margin and the iliac crest at end-expiration, and hip circumference at the level of the greater trochanters, both using a non-stretchable tape. WHtR was calculated as waist circumference divided by height, and WHR as waist circumference divided by hip circumference. BMI was calculated as weight (kg)/height² (m²) and interpreted using WHO age- and sex-specific percentile charts, with overweight defined as BMI ≥85th percentile and obesity as BMI ≥97th percentile for age and sex.

Statistical Analysis

Data were analysed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Continuous variables were summarised as mean ± standard deviation and compared using the independent Student's t-test or one-way ANOVA. Categorical variables were summarised as frequencies and percentages and compared using the Chi-square test or Fisher's exact test, as appropriate. Pearson correlation coefficients assessed the strength of association between WHR, WHtR, and BMI. ROC curve analysis was used to determine the area under the curve (AUC), optimal cut-offs, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of WHR and WHtR for detecting overweight and central obesity. A two-tailed p-value <0.05 was considered statistically significant.

Results And Discussion

A. Baseline Characteristics

Of 824 children enrolled, the mean age was 13.05±1.42 years, with a relatively even distribution across the 11- to 15-year age bands (18.1%–23.1% per year). Boys constituted 53.3% (n=439) and girls 46.7% (n=385) of the cohort. Mean outdoor activity was 1.49±0.65 h/day, screen time 1.59±0.67 h/day, sleep duration 8.97±2.03 h,

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and junk food consumption 2.16±1.39 times/week. A history of chronic disease was present in only 1.6% of children, and 12.7% reported a family history of non-communicable disease. Anthropometric characteristics are summarised in Table 1.

Table 1: Baseline demographic, lifestyle, and anthropometric characteristics of the study population (N=824)

Parameter	Value
Age (years), mean ± SD	13.05 ± 1.42
Male, n (%)	439 (53.3%)
Female, n (%)	385 (46.7%)
Weight (kg), mean ± SD	42.69 ± 12.92
Height (cm), mean ± SD	151.13 ± 11.90
BMI (kg/m²), mean ± SD	18.36 ± 3.86
Waist circumference (cm), mean ± SD	66.27 ± 9.53
Hip circumference (cm), mean ± SD	74.28 ± 9.50
Waist–hip ratio (WHR), mean ± SD	0.89 ± 0.05
Waist–height ratio (WHtR), mean ± SD	0.44 ± 0.05
Overweight (BMI ≥85th centile), n (%)	125 (15.2%)
Central obesity (BMI ≥97th centile), n (%)	29 (3.5%)
Acanthosis nigricans, n (%)	11 (1.3%)
History of chronic disease, n (%)	13 (1.6%)
Family history of NCD, n (%)	105 (12.7%)

B. Prevalence of Overweight and Central Obesity

The prevalence of overweight (BMI ≥85th percentile) in this cohort was 15.2% (n=125), and central obesity (BMI ≥97th percentile) was present in 3.5% (n=29). These figures closely parallel comparable Indian and international school-based studies: Krishnan et al [9] reported an overweight prevalence of 16.7% among school children in North Kerala, while Singh et al [8] documented a pooled Indian overweight prevalence of 12.4%. International data from Rönnecke et al [10] (15.4% in German children) and Bacopoulou et al [11] (15.3% in Greek adolescents) are similarly concordant. Reported prevalence figures vary widely across settings, from approximately 5% [10] to over 23% [11], reflecting differences in population characteristics, socioeconomic context, and the anthropometric cut-offs applied. For central obesity (general obesity by BMI ≥97th centile), the present 3.5% figure is similarly consistent with Panjikkaran et al [13] (3.2%) and Rönnecke et al [10] (2.8%), though some Indian regional estimates range considerably higher [8].

C. Correlation of Anthropometric Indices with BMI

WHR and WHtR showed markedly different relationships with BMI and with each other. WHR was

weakly correlated with BMI, whereas WHtR demonstrated a strong, near-linear relationship with BMI. WHtR also correlated strongly with waist and hip circumference, while WHR showed much weaker associations with these same parameters. The two indices were themselves moderately correlated with one another, indicating that while related, they capture overlapping but distinct dimensions of body composition (Table 2).

Table 2: Pearson correlation of waist–hip ratio and waist–height ratio with BMI and other anthropometric and physiological parameters

Parameter	WHR	WHtR
BMI	r=0.235, p<0.001	r=0.725, p<0.001
Waist circumference	r=0.444, p<0.001	r=0.831, p<0.001
Hip circumference	r=0.078, p=0.025	r=0.700, p<0.001
Weight	r=0.171, p<0.001	r=0.513, p<0.001
Height	r=0.019, p=0.582	r=0.007, p=0.839
WHR vs WHtR	—	r=0.529, p<0.001
Pulse rate	r=0.044, p=0.205	r=0.099, p=0.004
Perfusion index	r=0.032, p=0.364	r=0.102, p=0.003

WHtR's strong correlation with BMI is consistent with Krishnan et al [9] (r=0.764) and Dobashi et al [14] (r=0.564 with BMI percentile), while WHR's weak correlation parallels the negligible association (r=0.089) reported by Krishnan et al [9]. Notably, WHtR appears more sensitive than BMI alone in flagging at-risk children: Panjikkaran et al [13] found 16.8% of children "at risk" by WHtR versus only 8% overweight by BMI, and Kuriyan et al [12] reported 21% with WHtR >0.5 against just 7.8% overweight by BMI criteria, suggesting WHtR may capture central adiposity that BMI underestimates.

D. Association with Clinical and Anthropometric Parameters

Both overweight and centrally obese children showed significantly higher weight, waist circumference, and hip circumference than their peers, as well as significantly higher WHR and WHtR (Table 3). The magnitude of difference, however, was consistently larger for WHtR than for WHR across both outcome groups, foreshadowing its superior discriminatory performance on ROC analysis (subsection E).

Table 3: Association of waist–hip ratio and waist–height ratio with overweight, central obesity, and acanthosis nigricans

Group	n	WHR, mean ± SD	p-value	WHtR, mean ± SD	p-value
Overweight: Yes (n=125)	125	0.91 ± 0.05	<0.001*	0.51 ± 0.05	<0.001*
Overweight: No (n=699)	699	0.89 ± 0.05		0.43 ± 0.04	
Central obesity: Yes (n=29)	29	0.91 ± 0.05	0.017*	0.54 ± 0.06	<0.001*

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Central obesity: No (n=795)	795	0.89 ± 0.05		0.43 ± 0.05	
Acanthosis nigricans: Yes (n=11)	11	0.92 ± 0.04	0.090	0.52 ± 0.06	<0.001*
Acanthosis nigricans: No (n=813)	813	0.89 ± 0.05		0.43 ± 0.05	

*Statistically significant ($p<0.05$); Independent t-test used for all comparisons.

The marked elevation of WHtR (0.52 vs 0.43, $p<0.001$) but not WHR (0.92 vs 0.89, $p=0.090$) in children with acanthosis nigricans — a clinical marker of insulin resistance — is a particularly notable finding, suggesting that WHtR tracks more closely with insulin-resistance-related phenotypes than WHR in this age group. This is consistent with WHtR's established role as a marker more sensitive to metabolically relevant central fat than hip-referenced indices, which can be confounded by pelvic skeletal width and pubertal changes in body shape [16].

E. Diagnostic Performance of WHR and WHtR

ROC curve analysis was performed to evaluate the diagnostic accuracy of WHR and WHtR for detecting overweight and central obesity (Table 4, Figures 1 and 2). WHtR substantially outperformed WHR for both outcomes. For overweight, WHtR achieved an AUC of 0.891 versus 0.650 for WHR; for central obesity, WHtR achieved an AUC of 0.903 versus 0.642 for WHR. At its optimal cut-off of >0.48, WHtR identified central obesity with 86.2% sensitivity, 85.0% specificity, and an exceptionally high negative predictive value of 99.4%, making it especially useful for ruling out central obesity in a school screening context. WHR, by contrast, showed consistently lower sensitivity at its corresponding cut-offs, despite reasonable specificity, reflecting its limited ability to correctly flag children who truly have central obesity.

Table 4: Diagnostic performance of waist–hip ratio and waist–height ratio for detecting overweight and central obesity (ROC analysis)

Index – Outcome	AUC	95% CI	Cut-off	Sens.	Spec.	PPV	NPV
WHR – Overweight	0.650	0.616–0.683	>0.89	68.0%	56.2%	21.7%	90.8%
WHtR – Overweight	0.891	0.868–0.911	>0.46	83.2%	82.5%	46.0%	96.5%
WHR – Central Obesity	0.642	0.608–0.675	>0.93	44.8%	82.6%	8.6%	97.6%
WHtR – Central Obesity	0.903	0.881–0.923	>0.48	86.2%	85.0%	17.4%	99.4%

AUC = area under the ROC curve; CI = confidence interval; Sens. = sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value. All AUC values significant at $p<0.05$.

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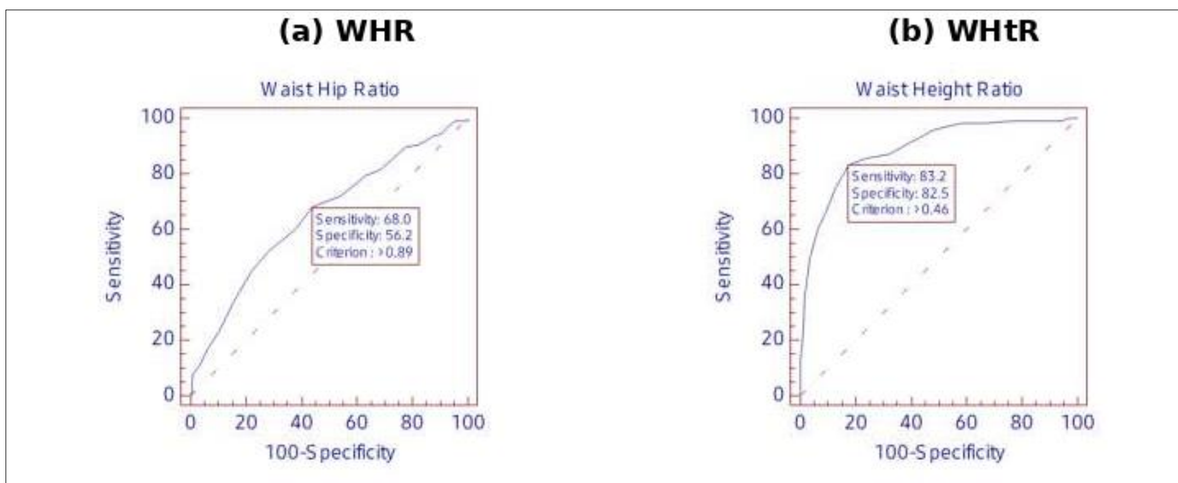

Figure 1: Receiver operating characteristic (ROC) curves for detection of overweight using (a) waist-hip ratio and (b) waist-height ratio.

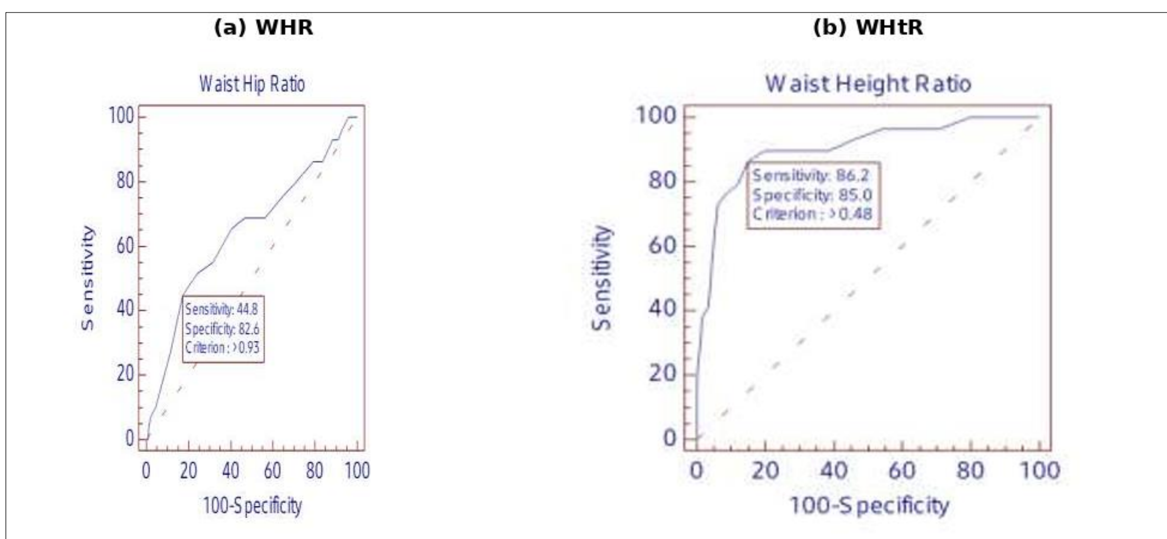

Figure 2: Receiver operating characteristic (ROC) curves for detection of central obesity using (a) waist-hip ratio and (b) waist-height ratio.

These findings closely mirror the wider literature. Bacopoulou et al [11] reported markedly lower WHR sensitivities (22–24%) at high specificity for general obesity, attributing this to confounding by pelvic width and body proportions, an observation also made by Mushtaq et al [16] and Krishnan et al [9], who concluded WHR is not a useful predictor of central adiposity in paediatric populations. Conversely, Bacopoulou et al [11] reported even higher WHtR performance (AUC 0.945–0.992) using a 0.5 cut-off with 91% sensitivity and 95% specificity, and Krishnan et al [9] identified WHtR as the strongest waist-based predictor of overweight and obesity (odds ratio 7.4). Brambilla et al [17] and Marrodán et al [18] similarly confirmed that WHtR outperforms waist circumference alone in predicting adiposity.

Not all evidence is unanimous: Hubert et al [19] concluded that waist circumference alone may be more sensitive and specific than WHtR for diagnosing obesity in some cohorts, and Widjaja et al [15] found WHR to be the stronger predictor of metabolic syndrome (rather than

central obesity per se) in obese adolescents, with WHR carrying the highest odds ratio in their multivariate model. Such findings indicate that the optimal index may depend on the specific outcome being predicted — general/central obesity versus broader metabolic syndrome risk — and underscore that WHtR and WHR may provide complementary, rather than interchangeable, information. In the present study population, however, where the outcome of interest was BMI-defined central obesity, WHtR was unambiguously the superior screening index across every diagnostic parameter examined.

F. Strengths and Limitations

This study's strengths include a large sample size, standardised measurement technique with calibrated instruments, and simultaneous evaluation of multiple anthropometric indices against a common outcome definition, allowing direct comparison. Limitations include the cross-sectional design, which precludes causal inference; restriction to private urban schools in a single city, limiting generalisability to rural or lower socioeconomic populations; reliance on self-reported lifestyle variables; and the absence of biochemical confirmation of metabolic risk or longitudinal follow-up to track index trajectories through puberty.

Conclusion

In this cohort of 824 school-going children aged 11 to 15 years, the prevalence of overweight and central obesity was 15.2% and 3.5%, respectively. Waist-height ratio showed a substantially stronger correlation with BMI than waist-hip ratio and demonstrated markedly superior diagnostic accuracy for detecting both overweight (AUC 0.891 vs 0.650) and central obesity (AUC 0.903 vs 0.642). WHtR was also significantly associated with acanthosis nigricans, a clinical correlate of insulin resistance, while WHR was not. These findings support the use of WHtR, with a practical cut-off around 0.48, as a simple, low-cost, and reliable tool for school-based screening of central obesity in early adolescence, enabling earlier identification of children who may benefit from preventive lifestyle intervention.

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