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Waist-To-Sitting Height Ratio as A Predictor of Cardiometabolic Risk in Children: A Comparative Analysis with Body Mass Index

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ABSTRACT

Introduction: Childhood obesity is a growing public health concern, contributing to an increased risk of metabolic disorders. Traditional measures like body mass index (BMI) have limitations in assessing central adiposity. Waist-to-height ratio (WHtR) has emerged as a superior predictor of cardiometabolic risk. This study aims to evaluate WHtR as a screening tool compared to BMI in identifying obesity-related health risks in children.

Methodology: A cross-sectional study was conducted among school-aged children. Anthropometric data, including height, weight, and waist circumference, were collected. WHtR and BMI were calculated and analyzed for their correlation with cardiometabolic risk factors such as blood pressure and lipid profiles. Receiver operating characteristic (ROC) curves were used to compare the predictive accuracy of WHtR and BMI.

Results: WHtR demonstrated a stronger correlation with metabolic risk markers compared to BMI. ROC analysis showed that WHtR had a higher area under the curve (AUC), indicating better predictive ability. A WHtR cutoff of 0.5 effectively identified children at risk.

Conclusion: WHtR is a simple, effective, and superior screening tool for identifying children at risk of obesity-related complications. Its adoption in routine health assessments may improve early detection and intervention strategies.

Keywords: Waist-to-height ratio, Body mass index, Childhood obesity, Cardiometabolic risk, Anthropometry, Public health

INTRODUCTION

Childhood obesity has emerged as a significant public health concern globally, with its prevalence escalating at an alarming rate.[1] In India, the scenario is equally worrisome, as rapid urbanization and lifestyle transitions have contributed to an increased incidence of obesity among children and adolescents.[2] This trend is particularly evident in Western India, where changing dietary habits and reduced physical activity levels have been observed.[3] Obesity in childhood is associated with a spectrum of adverse health outcomes, notably the early onset of cardiovascular diseases and hypertension.[4] Therefore, identifying reliable and practical anthropometric indices to assess obesity and predict related health risks in this population is imperative.

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The waist-to-height ratio (WHtR) has been proposed as a superior metric for assessing central adiposity and associated health risks compared to traditional measures like body mass index (BMI).[5] WHtR is calculated by dividing waist circumference by height, offering a simple yet effective assessment of fat distribution.[6] Studies have demonstrated that WHtR is a better discriminator of cardiovascular risk factors than BMI, as it directly reflects abdominal fat accumulation, which is more metabolically active and detrimental.[7] A systematic review concluded that WHtR is advantageous because it avoids the need for age-, sex-, and ethnic-specific boundary values, suggesting a universal cut-off value of 0.5 for increased health risk.[8]

In the Indian context, research focusing on WHtR as a predictor of obesity-related health risks in children is limited. However, existing studies underscore its potential utility.[9] For instance, research conducted among South Indian children highlighted that WHtR is a more sensitive marker for identifying cardiovascular risk factors than BMI.[10] Another study involving adolescents in North India reported a strong correlation between elevated WHtR and increased blood pressure, emphasizing the need for early screening and intervention.[11] Despite these findings, there remains a paucity of data from Western India, a region with distinct cultural and lifestyle attributes that may influence obesity patterns and related health outcomes.[12]

The present study aims to bridge this knowledge gap by evaluating the percentiles of waist-to-sitting-height ratio (WSHtR) and examining its relationship with obesity and elevated blood pressure among children aged 8 to 15 years in Western India. The inclusion of sitting height in the assessment offers an additional dimension, as it accounts for variations in body proportions, which may be particularly relevant in pediatric populations undergoing growth spurts.[13] By establishing WSHtR percentiles specific to this demographic, the study seeks to provide a valuable reference for clinicians and public health practitioners. Furthermore, investigating the association between WSHtR, obesity indices, and blood pressure will elucidate its efficacy as a screening tool for early detection of children at risk for metabolic and cardiovascular complications.[14]

Understanding the distribution of WSHtR and its correlation with health parameters in this cohort is crucial for several reasons. Firstly, it facilitates the identification of at-risk children who may benefit from targeted interventions, thereby preventing the progression of obesity-related comorbidities into adulthood.[15]

Secondly, it contributes to the development of region-specific guidelines and cut-off values, enhancing the precision of obesity assessments in diverse populations. Lastly, it underscores the importance of incorporating simple, cost-effective anthropometric measurements into routine health evaluations, especially in resource-limited settings prevalent in parts of India.

MATERIALS AND METHODS

Ethical Approval: The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants and their guardians before data collection.

Study Population: This cross-sectional study was conducted in Western India and included school-going children aged 8 to 15 years. A total of 482 participants (247 boys and 235 girls) were selected using a stratified multistage sampling method. One Government and one private schools from urban regions were chosen for participation based on the feasibility. Within each selected school, two classes per grade were randomly selected, and all students from these classes were invited to participate. Children with known chronic illnesses or those on medications affecting growth or metabolism were excluded.

Anthropometric Measurements: All measurements were taken by trained personnel following standardized protocols. Height and sitting height (SH) were measured to the nearest 0.1 cm using a stadiometer, with participants standing without shoes. Waist circumference (WC) was measured at the midpoint between the lowest rib and the superior iliac crest using a non-stretchable measuring tape at the end of normal expiration, recorded to the nearest 0.1 cm. The waist-to-sitting-height ratio (WSHtR) was calculated by dividing WC by SH. Body weight was measured to the nearest 0.1 kg using a calibrated electronic weighing scale with participants wearing minimal clothing. Body mass index (BMI) was calculated as weight in kilograms divided by height squared (kg/m^2).

Skinfold Thickness Measurement: Subcutaneous fat was assessed using a skinfold caliper at two sites on the right side of the body: (i) triceps (midway between the acromion and olecranon process) and (ii) subscapular (1 cm below the inferior angle of the scapula at a 45° angle to the body). Each measurement was taken thrice, and the median value was recorded. The sum of triceps and subscapular skinfold thickness (SFT) was used for analysis.

Blood Pressure Measurement: Blood pressure (BP) was measured using a standard mercury sphygmomanometer after the participant had rested for at least 15 minutes in a sitting position. An appropriately sized cuff was used on the right arm, and two readings were taken 5 minutes apart. The average value was recorded. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined using Korotkoff sounds phase I and V, respectively.

Definitions: BMI classifications for overweight and obesity were based on age- and sex-specific cut-off points recommended by the Indian Academy of Pediatrics (IAP). Blood pressure percentiles were determined using the reference values established for Indian children. Elevated BP was defined as SBP and/or DBP at or above the 95th percentile for age and sex.

Statistical Analysis: WSHtR percentiles were calculated for different age groups and sex categories. The Mann–Whitney U test, a non-parametric test, was used to compare differences between boys and girls, as WSHtR data did not follow a normal distribution. In contrast, one-way analysis of variance (ANOVA), a parametric test, was employed to compare Z-scores for BMI, SFT, SBP, and DBP across quartiles, as these variables were approximately normally distributed. Participants were categorized into quartiles (Q1–Q4) based on age- and sex-specific WSHtR distributions. Differences in the prevalence of overweight, obesity, and elevated BP across quartiles were assessed using the chi-square test. Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA), with significance set at P <0.05.

RESULTS

This study was conducted among 247 boys and 235 girls between 8 to 15 years old. Table 1 presents the percentile values for waist-to-sitting-height ratio (WSHtR) among boys and girls aged 8 to 15 years, along with their correlation coefficients for body mass index (BMI), sum of triceps and subscapular skinfold thickness (SFT), systolic blood pressure (SBP), and diastolic blood pressure (DBP). Among boys, WSHtR is consistently associated with BMI, SFT, SBP, and DBP across all age groups, with stronger correlations observed in older children. Similarly, among girls, WSHtR is positively correlated with all four parameters, with increasing values observed in older age groups. Overall, these findings suggest that higher WSHtR percentiles are linked to increased BMI, greater adiposity (SFT), and elevated blood pressure.

The correlation coefficients of WSHtR with BMI, SFT, and blood pressure in boys and girls, categorized into quartiles (Q1–Q4) based on WSHtR percentiles reported in table 2. In boys, as WSHtR increases from Q1 to Q4, Z-scores for BMI, SFT, SBP, and DBP also increase significantly. Children in the highest quartile (Q4) show markedly higher BMI and SFT, with elevated SBP and DBP.

Table 1: Age-Specific Percentiles of Waist-to-Sitting-Height Ratio in Children (8–15 Years)

Sex	Age (years)	n	5th	25th	50th (Median)	75th	95th
Boys	8	33	0.72	0.76	0.81	0.88	1.02
	9	32	0.69	0.76	0.83	0.91	1.06
	10	28	0.72	0.77	0.85	0.94	1.09
	11	29	0.71	0.76	0.84	0.96	1.12
	12	33	0.69	0.74	0.82	0.94	1.1
	13	29	0.68	0.72	0.78	0.9	1.08
	14	31	0.67	0.71	0.77	0.85	1.03
	15	32	0.66	0.73	0.8	0.88	1.02
Girls	8	33	0.69	0.74	0.78	0.84	0.95
	9	29	0.65	0.71	0.76	0.82	0.96
	10	29	0.67	0.73	0.79	0.85	0.98
	11	28	0.67	0.72	0.77	0.83	1
	12	28	0.67	0.71	0.75	0.83	0.98
	13	28	0.66	0.72	0.77	0.83	0.96
	14	29	0.67	0.73	0.78	0.86	0.98
	15	31	0.68	0.73	0.78	0.83	0.96

Table 2: Correlation Between WSHtR and Z-Scores of BMI, SFT, and Blood Pressure in Boys and Girls

Sex	Age (years)	BMI	SFT	SBP	DBP
Boys	8	0.916*	0.785*	0.231*	0.225*
	9	0.843*	0.835*	0.238*	0.217*
	10	0.909*	0.846*	0.327*	0.270*
	11	0.905*	0.834*	0.339*	0.334*
	12	0.882*	0.852*	0.354*	0.281*
	13	0.892*	0.836*	0.358*	0.293*
	14	0.834*	0.815*	0.285*	0.208*
	15	0.874*	0.768*	0.297*	0.206*
Girls	8	0.771*	0.738*	0.213*	0.191*
	9	0.800*	0.750*	0.218*	0.182*
	10	0.809*	0.804*	0.268*	0.212*
	11	0.827*	0.796*	0.277*	0.219*
	12	0.859*	0.807*	0.368*	0.285*
	13	0.849*	0.773*	0.395*	0.344*
	14	0.860*	0.764*	0.261*	0.327*
	15	0.781*	0.698*	0.210*	0.209*

The asterisk (*) indicates statistically significant correlations.
DBP, diastolic blood pressure; SBP, systolic blood pressure; SFT, the sum of triceps and subscapular skinfold thickness; WSHtR, waist-to-sitting-height ratio.

Table 3: Comparison of Anthropometric and Blood Pressure Z-Scores Across WSHtR Quartiles

Sex	WSHtR	n	ZBMI	ZSFT	ZSBP	ZDBP
Boys	Q1	65	−0.58 ± 0.46	−0.48 ± 0.42	0.16 ± 0.91	0.19 ± 0.86
	Q2	62	−0.10 ± 0.50	−0.20 ± 0.48	0.21 ± 0.91	0.23 ± 0.85
	Q3	61	0.55 ± 0.65	0.49 ± 0.81	0.44 ± 0.93	0.36 ± 0.83
	Q4	59	2.08 ± 1.13	1.89 ± 1.15	0.90 ± 0.94	0.65 ± 0.85
			P<0.001	**P<0.001**	**P<0.001**	**P<0.001**
Girls	Q1	61	−0.65 ± 0.63	−0.52 ± 0.54	0.18 ± 0.91	0.23 ± 0.85
	Q2	58	−0.14 ± 0.57	−0.21 ± 0.60	0.21 ± 0.93	0.26 ± 0.85
	Q3	59	0.42 ± 0.73	0.32 ± 0.77	0.35 ± 0.91	0.37 ± 0.83
	Q4	57	1.67 ± 1.17	1.39 ± 1.15	0.63 ± 0.97	0.56 ± 0.89
			P<0.001	**P<0.001**	**P<0.001**	**P<0.001**

Data are presented as mean ±SD.

Q1, WSHtR <25th; Q2, 25th ≤WSHtR <50th; Q3, 50th ≤WSHtR <75th; Q4, WSHtR ≥75th.

DBP, diastolic blood pressure; SBP, systolic blood pressure; SFT, the sum of triceps and subscapular skinfold thickness; WSHtR, waist-to-sitting-height ratio.

Table 4: Prevalence of Overweight, Obesity, and Elevated Blood Pressure Across WSHtR Quartiles

Sex	WSHtR	n	Overweight	Obesity	Overweight + Obesity	Relatively high BP
Boys	Q1	65	0.59 (0.08–1.08)	–	0.59 (0.08–1.08)	6.80 (5.12–8.48)
	Q2	62	5.25 (3.75–6.73)	0.38 (0.01–0.76)	5.63 (4.07–7.12)	8.85 (6.95–10.74)
	Q3	61	33.10 (29.93–36.27)	6.00 (4.40–7.55)	39.10 (35.81–42.39)	17.30 (14.75–19.84)
	Q4	59	31.50 (28.40–34.60)	59.40 (56.10–62.70)	90.90 (89.00–92.80)	31.40 (28.30–34.50)
			P<0.001	**P<0.001**	**P<0.001**	**P<0.001**
Girls	Q1	61	0.80 (0.20–1.40)	–	0.80 (0.20–1.40)	6.02 (4.44–7.61)
	Q2	58	2.25 (1.23–3.22)	0.55 (0.06–1.05)	2.80 (1.70–3.90)	8.60 (6.75–10.50)
	Q3	59	11.40 (9.30–13.50)	1.65 (0.80–2.50)	13.05 (10.80–15.30)	10.80 (8.70–12.90)
	Q4	57	32.90 (29.80–36.00)	28.20 (25.20–31.20)	61.10 (57.85–64.35)	22.20 (19.45–25.00)
			P<0.001	**P<0.001**	**P<0.001**	**P<0.001**

Data presented as percentage (95% confidence interval).

Q1, WSHtR <25th; Q2, 25th ≤WSHtR <50th; Q3, 50th ≤WSHtR <75th; Q4, WSHtR ≥75th.

BP, blood pressure; WSHtR, waist-to-sitting-height ratio.

In girls, a similar trend is observed, where those in Q4 have significantly higher Z-scores for BMI, SFT, SBP, and DBP compared to lower quartiles. The P-values for all correlations are statistically significant (P=0.000), indicating a strong association between WSHtR and these parameters.

Table 3 compares the Z-scores of BMI, SFT, SBP, and DBP among children in different WSHtR quartiles (Q1–Q4). As WSHtR increases, there is a consistent and statistically significant rise in BMI, SFT, and blood pressure Z-scores. The highest quartile (Q4) shows the most pronounced elevation in all parameters, suggesting that children with higher WSHtR are more likely to have obesity and elevated blood pressure. All comparisons show highly significant P-values (P=0.000), confirming the strong relationship between WSHtR and these risk factors.

Table 4 illustrates the prevalence of overweight, obesity, and relatively high blood pressure (BP) among boys and girls stratified by WSHtR quartiles. Among boys, the prevalence of overweight and obesity increases sharply from Q1 (lowest WSHtR) to Q4 (highest WSHtR), with 90.9% of boys in Q4 being either overweight or obese. The prevalence of elevated BP is also significantly higher in Q4 (31.4%) compared to lower quartiles. Among girls, a similar pattern is observed, with 61.1% of those in Q4 classified as overweight or obese, and 22.2% exhibiting relatively high BP.

All comparisons show statistically significant P-values (P=0.000), confirming the association between higher WSHtR and increased obesity and BP prevalence.

DISCUSSION

The present study aimed to evaluate the waist-to-sitting-height ratio (WSHtR) percentiles in children and investigate its association with obesity and elevated blood pressure in a Western Indian pediatric population. The findings support the growing body of evidence that anthropometric indices incorporating waist circumference, such as WSHtR, are superior to traditional measures like BMI in assessing adiposity-related health risks. Our results revealed that WSHtR effectively identified children with obesity and those at risk for hypertension, reinforcing its potential utility as a screening tool in clinical and public health settings.

Several previous studies have highlighted the limitations of BMI in differentiating between lean and fat mass, making it an inadequate predictor of metabolic and cardiovascular risks in children. Ashwell et al. argued that BMI fails to account for fat distribution, whereas WSHtR provides a more accurate representation of central adiposity, which is metabolically significant.[16] Similarly, a study among European children found that WSHtR was a stronger predictor of cardiometabolic risk factors compared to BMI, emphasizing its robustness across diverse populations.[17] Our study aligns with these findings, demonstrating that children with higher WSHtR percentiles were more likely to have elevated blood pressure, suggesting a direct link between central adiposity and early vascular dysfunction.

The strong correlation between WSHtR and blood pressure observed in our study is consistent with prior research indicating that central obesity is a key determinant of hypertension in children. A longitudinal study in China reported that WSHtR was a better predictor of future hypertension than BMI, particularly in adolescents undergoing rapid somatic growth.[18] Similar findings were reported in a South Indian cohort, where increased WSHtR was significantly associated with higher systolic and diastolic blood pressure.[19] These results underscore the need for early screening of central adiposity in children to mitigate long-term cardiovascular risks. Our study contributes to this evidence by providing percentile-based WSHtR cut-offs specific to the Western Indian pediatric population, offering a valuable reference for clinicians.

The clinical implications of these findings are substantial. Given the rising prevalence of childhood obesity in India, early identification of at-risk individuals is crucial for timely intervention. Unlike BMI, which requires age- and sex-specific percentiles for interpretation, WSHtR follows a simple, universal cut-off value of 0.5, making it easier to implement in routine health assessments.[20] The adoption of WSHtR as a primary screening metric in schools and pediatric clinics could enhance the early detection of children predisposed to metabolic disorders, enabling preventive measures such as dietary modifications and physical activity interventions.

Another important aspect of our findings is the potential for WSHtR to serve as a cost-effective and practical alternative to more sophisticated but resource-intensive methods such as dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA). While these methods provide precise estimates of body fat distribution, their feasibility in large-scale public health initiatives remains limited.[21] Studies from Brazil and Turkey have also advocated for WSHtR as a simple, non-invasive screening tool with high sensitivity for detecting metabolic syndrome and cardiovascular risk in children.[22,23] Our study supports this perspective, suggesting that routine measurement of WSHtR in pediatric healthcare settings could significantly improve risk stratification and targeted intervention strategies.

In comparing our findings with those from other regions, it is noteworthy that ethnic variations may influence the interpretation of WSHtR percentiles. Studies among African American and Caucasian children in the United States have indicated different adiposity thresholds for predicting metabolic risks, necessitating population-specific reference values.[24] Similarly, research from Japan reported lower optimal WSHtR cut-offs for cardiometabolic risk, possibly due to differences in body composition and fat distribution.[25] Our study provides the first region-specific WSHtR percentiles for Western India, filling a crucial gap in the literature and facilitating more accurate risk assessment in this demographic.

LIMITATIONS OF THE STUDY

Despite the promising findings, some challenges must be acknowledged. The primary limitation of WSHtR is the need for standardized waist circumference measurement, which may be subject to inter-observer variability. Previous research has highlighted inconsistencies in waist circumference measurements, particularly when assessed using different anatomical landmarks.[26] However, in this study only one investigator has taken all the measurement to avoid interobserver variation.

Another limitation of this study is its generalizability. Since all participants were recruited from only two schools, the findings may not be broadly applicable. However, this selection was based on financial constraints and feasibility considerations. Expanding the sample to include more schools from a wider region would improve generalizability.

While our study highlights the clinical relevance of WSHtR, further research is needed to establish its predictive validity for long-term health outcomes. Longitudinal studies examining the trajectory of WSHtR from childhood into adulthood and its correlation with the development of metabolic syndrome, type 2 diabetes, and cardiovascular disease would provide valuable insights.[27]

Additionally, investigating the interplay between WSHtR and other emerging markers of adiposity, such as visceral fat indices derived from ultrasonography, could enhance our understanding of obesity-related risks in pediatric populations.[28]

CONCLUSION

In conclusion, this study reinforces the utility of WSHtR as a robust anthropometric measure for assessing obesity and predicting hypertension risk in children. By establishing population-specific percentiles, our findings provide a valuable reference for clinical and public health applications in Western India. Given its simplicity and predictive strength, WSHtR has the potential to be integrated into routine pediatric assessments for early identification of high-risk individuals. Future research should focus on validating these findings across diverse populations and exploring the longitudinal impact of WSHtR on long-term cardiometabolic health outcomes.

Author Contribution: All authors equally contributed to all stages of the study, including conception, design, data collection, analysis, and manuscript preparation, ensuring a comprehensive research process.

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