ORIGINAL ARTICLE

Waist-to-Height Ratio as a Screening Marker of Elevated Blood Pressure in School-going Adolescents in North India

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Abstract
Introduction: The incidence of obesity and lifestyle changes have increased cardiovascular diseases (CVDs) prevalence, including diabetes and hypertension. Studies demonstrate that waist-height ratio (WHtR) correlates more strongly with cardiovascular risk variables than Body Mass Index and Waist Circumference. **Objectives:** To assess if waist to height (WHtR) ratio can be used as a future predictor of adult hypertension. **Methods:** This study assessed whether WHtR effectively screens for hypertension among school-going adolescents through a cross-sectional study examining 800 children aged 12-14 years in Aligarh Muslim University high schools using pre-tested questionnaires. Children present during examination and willing to participate were included, while those with preexisting comorbidities were excluded. Statistical analysis utilized IBM SPSS version 20.0. **Results:** The mean waist size measured 64.9±9.19 cm, with mean WHtR of 0.42±0.05 and mean systolic blood pressure of 110±12.7 mmHg. A statistically significant association (p=0.00) existed between systolic blood pressure and WHtR. Regression analysis revealed WHtR as a statistically significant systolic blood pressure predictor (R^2=0.018, p=0.000). **Conclusion:** The waist-height ratio serves as a valid hypertension risk predictor in adulthood, emphasizing the necessity for early preventative efforts and lifestyle adjustments during adolescence to improve this ratio and reduce future cardiovascular disease risk.

Keywords
Waist- height ratio, blood pressure, adolescents, school going, screening

Introduction
Hypertension among children and adolescents is a growing public health concern. Elevated blood pressure (BP) in childhood is a well-established predictor of adult hypertension and cardiovascular disease (CVD), as hypertensive CVD has its roots in early life(1). With evolving diagnostic criteria and increasing childhood obesity, the prevalence of raised BP and hypertension in children is rising globally(2).

Body Mass Index (BMI), though widely used, cannot differentiate fat mass from fat-free mass and underestimates central adiposity. Waist-to-height ratio (WHtR) captures abdominal fat distribution and is associated

with adverse cardiometabolic profiles even in children with normal BMI(3). WHtR has a universal cut-off of 0.5, applicable across age, sex, and ethnicity, making it a simple, cost-effective screening tool(4), and has emerged as a more reliable cardiometabolic risk indicator than BMI(5). Despite extensive research on BMI and hypertension, data on WHtR as a predictor of hypertension in adolescents remain limited. This study therefore aimed to assess whether WHtR can serve as a future predictor of adult hypertension among school-going adolescents.

Despite substantial study on BMI and hypertension, there is limited information on WHtR's involvement in predicting hypertension in adolescents.

Aim: This study was undertaken among school going adolescents with an aim to assess if waist to height (WHtR) ratio can be used as a future predictor of adult hypertension.

Objectives

- To determine the prevalence of elevated waist-to-height ratio (WHtR ≥0.5) among school-going adolescents aged 12–14 years in Aligarh.
- To assess the association between waist-to-height ratio (WHtR) and systolic blood pressure among school-going adolescents.
- To evaluate WHtR as a screening tool for predicting elevated blood pressure in the adolescent population.

MATERIAL & METHODS

Study Design The current study was undertaken among school going adolescents between 12-14 years of age, in the high schools maintained by Aligarh Muslim University (AMU), Aligarh. The AMU maintains six high schools under its administration, of which three schools cater to boys and 3 are for female students.

Study type:A cross-sectional design was employed as part of the main study for primary outcome, simple random sampling was utilized to select the participants from a table of random numbers.

Sample size calculation: The sample size (n) was 709, which was rounded to 800, taking into account the prevalence of physical inactivity at 21% (6), the absolute allowable error at 3% with a 95% confidence level, and the non-response rate at 10%. The study period was from July 2018 to June 2019.

Although the parent study's primary goal was to assess physical inactivity, the current analysis, which examined the relationship between waist-to-height ratio (WHtR) and systolic blood pressure (SBP), was predetermined and carried out using the same information. During the first data collection, each subject received anthropometric and blood pressure measurements, including WHtR and SBP.

The present paper reports a prespecified secondary analysis examining associations between waist-to-height ratio (WHtR) and systolic blood pressure in the same sample. Thus, although the dataset was initially powered for the main aim of research being physical inactivity, it is precise enough for WHtR prevalence estimation and for detecting moderate-to-large effect sizes for testing associations.

Inclusion and exclusion criteria: The selected students, who were between the ages of 12 and 14, had to be willing to take the test and be present on the day of the exam. Children who were over 15 years old, did not show up on exam day, or were not cooperative were not allowed to participate.

Ethical clearance: The Institutional Ethics Committee of the Faculty of Medicine at Aligarh Muslim University gave its approval for the study to be conducted.

Before beginning the study, the AMU School Education Directorate obtained a signed consent from the principals of the relevant schools. The respondents were approached verbally for their assent to participate in the study after their parents or guardians gave their approval. The study excluded participants who declined to give their consent. Students were assured about the confidentiality of their identity and information during the test and interview.

Waist- height ratio (WHtR): Waist circumference was measured to nearest 0.1 cm during expiration with measurement taken at approximate midpoint between last palpable rib and iliac crest.Height was measured by using fixed stadiometer to

nearest 0.1 cm after contacting occiput, shoulder blades, buttocks and heels against the wall, optimal WHtR cut off value was taken as 0.5 in both male and female students(7).

Blood pressure (8): was measured by an electronic sphygmomanometer with an age appropriate cuff with an inflatable bladder; at least 40 percent of the arm circumference at a point midway between Olecranon and Acromion processes. Blood pressure was recorded in the sitting position in the right arm to the nearest 1mm Hg using electronic OMRON machine (Omron Corporation, Tokyo, Japan). Two readings were taken 5 minutes apart and the mean of the two was taken as the blood pressure. The blood pressure was classified according to paediatric hypertension guidelines (National High Blood Pressure Education Program) using age, sex and height specific percentile. Children having a systolic blood pressure of more than +2 SD were identified as having high blood pressure. Such students were counselled appropriately and referred for further investigations and management.

Statistical Analysis: Data were entered and analyzed using IBM SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). Continuous variables (e.g., waist circumference, height, systolic and diastolic blood pressure) were summarized as mean ± standard deviation (SD). Categorical variables (e.g., WHtR ≥0.5 vs. <0.5, elevated systolic BP vs. normal) were presented as proportions with 95% confidence intervals (CI). The chi-square test was applied to examine the association between WHtR categories and elevated systolic blood pressure. Mean differences in blood pressure between WHtR groups were compared using the independent samples *t*-test. Simple linear regression was performed with systolic blood pressure as the dependent variable and WHtR as the independent predictor to quantify the association, with β-coefficients, standard errors, 95% CI, and proportion of variance explained (R^2) reported. Logistic regression was also used to calculate odds ratios (OR) with 95% CI for elevated systolic blood pressure in adolescents with WHtR ≥0.5 compared to those with WHtR <0.5. A p-value <0.05 was considered statistically significant.

RESULTS

800 students were included in this study, with a comparatively even gender split across ages. (figure 1). The average waist circumference was recorded as 64.9 ± 9.19 cm, the average height that was observed was 151.36 ± 10.12 cm, and the average waist-height ratio (WtHR) was seen to be 0.42 ± 0.05. The average systolic blood pressure and diastolic blood pressure values were 110 ± 12.7 and 72.26 ± 8.50 mmHg, respectively. Though 12.62% (n=101) reported high ratios (≥0.5), the most of the subjects (87.38%, n=699) possessed normal WtHR values (<0.5). Likewise, 19.63% (n=157) reported high readings (≥120 mmHg) and 80.37% (n=643) possessed normal systolic blood pressure (<120 mmHg). Among the 800 study participants, systolic blood pressure (SBP) showed a clear distribution pattern with waist-to-height ratio (WHtR). In the normotensive group (SBP <120 mmHg), the majority had WHtR <0.5 (82.4%), while 66.3% had WHtR >0.5. In contrast, among those with elevated SBP (>120 mmHg), 33.6% had WHtR >0.5 compared to only 17.5% with WHtR <0.5. (figure 2).

The statistical significance proved a strong relationship between waist-height ratio and systolic blood pressure by the application of chi-square test ($\chi^2 = 14.442$, df = 1, $p < 0.001$, $r = 0.235$) (Table 1).

Contingency table analysis revealed that adolescents with WHTR ≥0.5 had a significant tendency to have increased systolic blood pressure, whereby only 66.37% of them had normal readings as opposed to 82.4% in the normal WtHR category. Linear regression analysis also supported this association, where WHtR (≥0.5) was a significant predictor of increased systolic blood pressure (β = 0.161, SE = 0.042, p = 0.000, F = 14.671, 95% CI: 0.078-0.243) (Table 2).

Though the model predicted 1.8% of systolic blood pressure variance ($R^2 = 0.018$), statistical significance and clinical applicability in this youth population confirm the merit of WtHR as a preliminary screening indicator of cardiovascular risk.

These results confirm a strong and statistically significant link between central adiposity, as

measured by waist-height ratio, and cardiovascular risk markers in adolescents. The evidence indicates that having a WtHR of less than 0.5 is related to improved blood pressure regulation, with adolescents above this threshold being about 2.3-fold more likely to have increased systolic blood pressure.

Table 1: Association Table Between Waist-Height Ratio And Systolic Blood Pressure

	Systolic Blood Pressure				
Waist- Height Ratio	Less than 120		More than 120		Total
Less than 0.5	576	82.4%	123	17.5%	699
Equal or more than 0.5	67	66.37%	34	33.63%	101
Total	643	80.37%	157	19.62%	800
X^2= 14.442, dF= 1, p= < .001, r= .235					

Table 2: Linear Regression Table To Predict Waist Height Ratio As A Screening Tool For High Blood Pressure

Variable	Coefficient (β)	S.E.	df	Sig. (p-value)	R2	F	95% CI (Lower–Upper)
Waist-Height Ratio (≥0.5)	.161	.042	1	0.000	.018	14.671	.078-.243

Figure 1: Demographic characteristics of study population

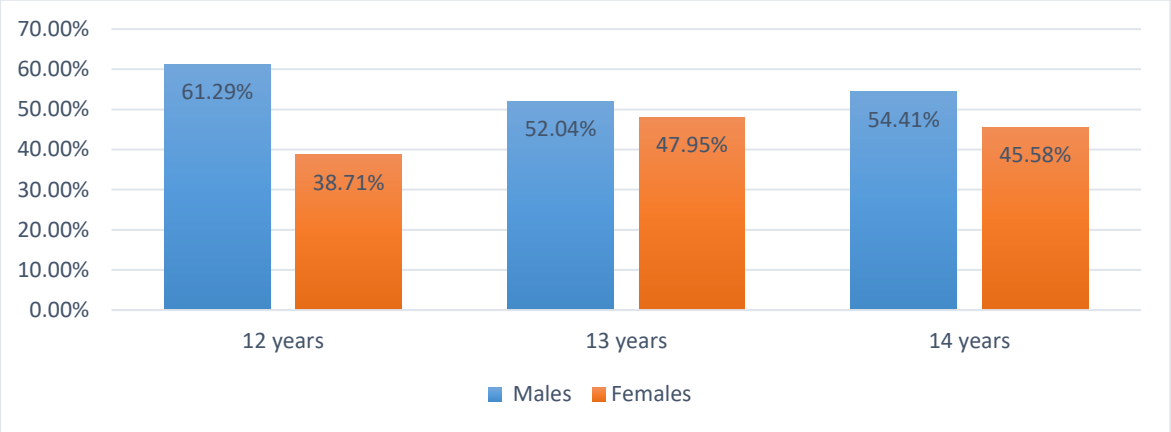
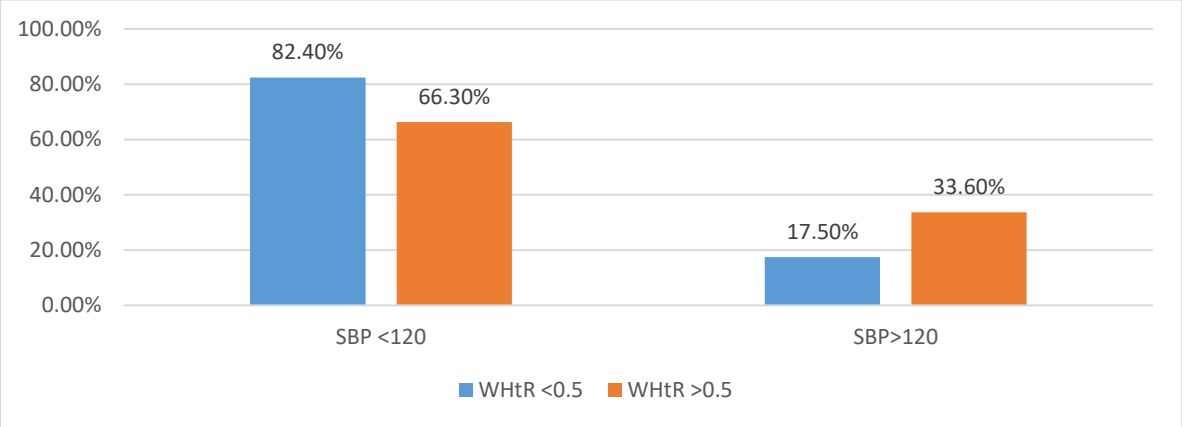


Figure 2: Overall Distribution of Blood Pressure and Waist-Height Ratio Among Study Population



DISCUSSION

The present study shows a statistically significant association between waist-height ratio (WtHR) and systolic blood pressure in adolescents in the 12-14 years age group, providing vital evidence for the developing literature examining central adiposity as a predictor of cardiovascular risk(1,7). Our

findings show that adolescents with WtHR ≥0.5 have 2.3-fold higher odds of high systolic blood pressure compared to the normal WtHR group, confirming clinical usefulness of this anthropometric measure as a screening tool in the pediatric population.

The classification of central adiposity as an independent risk factor for increased blood pressure is consistent with contemporary knowledge of cardiovascular pathophysiology of obesity (8,9). The average WtHR of 0.42 ± 0.05 in our study group, among whom 12.62% had high ratios (≥0.5), portrays trends consistent with international pediatric obesity epidemiology. The 0.5 cutpoint for WtHR has been widely tested across a wide range of populations as a clinically relevant threshold for the identification of increased cardiometabolic risk (1,10).

Current research has highlighted the superiority of central adiposity assessments to conventional BMI in the prediction of cardiovascular events(7,11). Our results are in support of this shift in paradigm since WtHR had definite discriminatory capacity in detecting adolescents at risk for increased blood pressure. This is all the more appropriate because central adiposity represents the accumulation of visceral fat, which is metabolically more active and highly linked with insulin resistance, systemic inflammation, and resultant cardiovascular dysfunction (9,12).

Gender-specific analysis of the findings showed significant differences with 90.40% of girls having healthy WtHR values against 84.98% of boys. This trend is in line with established understanding of adolescent development and body composition alterations that occur during puberty (8,11). The increased rates of higher WtHR in male adolescents indicate that gender-specific strategies for cardiovascular risk assessment and prevention programs are required (10,12).

Linear regression analysis provided a statistically significant correlation ($\beta = 0.161$, $p = 0.000$) between WtHR and raised systolic blood pressure despite accounting for a mere 1.8% of the variance. The chi-square test ($\chi^2 = 14.442$, $p < 0.001$) supported this correlation and indicated that a significantly lower proportion of adolescents with raised WtHR had normal blood pressure levels (66.37%) than were observed in the normal WtHR group (82.4%).

The correlation of central adiposity with increased blood pressure probably reflects interrelated pathophysiological pathways(9,11). Visceral adipose tissue releases several adipokines and inflammatory mediators involved in the endothelial dysfunction, insulin resistance, and activation of the renin-angiotensin-aldosterone system leading to increased blood pressure (10,12). The effects of excess adiposity are especially vulnerable to occur during adolescence because the changes of the cardiovascular system increase this vulnerability(1,8) .

Our results are consistent with current international studies that have explored WtHR and cardiovascular risk in children(1,7,8). The ease of WtHR measurement as it only needs height and waist circumference makes it useful to be applied in various healthcare settings, even resource-poor settings (7,8). It could be especially useful to apply in school health programs for effective population screening (7,10).

CONCLUSION

The current study presents strong evidence that waist-to-height ratio (WHtR) is a powerful predictor of raised systolic blood pressure, defining its potential role as an early screening index for cardiovascular risk in children. The global applicability of the cut-off for WHtR, with ease of measurement with no need of complicated apparatus or specialized equipment but only with simple anthropometric instruments, makes this measure an efficient and low-cost screening tool highly appropriate for resource-poor environments and mass population health programs. Since cardiovascular disease courses are set early in life, these results have major implications for preventive healthcare policy because the identification of central adiposity by means of WHtR measurement in school health programs could enable the institution of early prevention so that the development of adult hypertension and

resultant cardiovascular complications might be averted. Though cross-sectional design restricts causal inference and generalizability, the present study adds to the increasing evidence favoring WHtR as a better anthropometric measurement than the conventional BMI for cardiovascular risk stratification among adolescents. Health care providers and public health professionals should consider the inclusion of WHtR measurement as part of standard adolescent health screening, given the simplicity and applicability to all populations of this measure, making it most useful to school-based health programs and community screening programs geared to early detection of cardiovascular risk factors, recommending that it be integrated into pediatric preventive care pathways and population health surveillance systems.

RECOMMENDATION

Waist-to-height ratio (WHtR) should be integrated as a routine anthropometric measurement in school-based health screening programs, particularly for adolescents aged 12–14 years, given its simplicity, low cost, and demonstrated association with elevated systolic blood pressure. Health authorities and policymakers in India should consider incorporating WHtR (cut-off ≥0.5) alongside conventional blood pressure monitoring in pediatric preventive care guidelines. School health programs should prioritize lifestyle counselling, dietary modification, and physical activity promotion for adolescents identified with central adiposity. Public health educators should advocate for WHtR as a population-level screening tool, especially in resource-limited settings where advanced diagnostic equipment is unavailable. Gender-specific cardiovascular risk reduction strategies should be developed, given the observed higher prevalence of elevated WHtR among male adolescents. Early identification of at-risk adolescents through WHtR screening can facilitate timely referral and intervention, potentially reducing the burden of adult hypertension and associated cardiovascular disease.

LIMITATION OF THE STUDY

The cross-sectional design of this study precludes causal inference, and the direction of the relationship between WHtR and elevated blood pressure cannot be established with certainty. The study was conducted exclusively in schools administered by Aligarh Muslim University, which may limit the generalizability of findings to a broader or more diverse adolescent population in India. The sample comprised adolescents aged 12–14 years only, restricting applicability to other age groups. As this was a secondary analysis of data collected for a primary study on physical inactivity, the dataset was powered for the primary outcome rather than the current association, which may limit the precision of effect estimates. Dietary habits, physical activity levels, socioeconomic status, pubertal stage, and family history of hypertension were not controlled for, which may confound the observed associations. Diastolic blood pressure was not included as a primary outcome, limiting a comprehensive assessment of hypertensive status. A single-time measurement of blood pressure, despite the average of two readings, may not fully account for white-coat hypertension or diurnal variation. The absence of longitudinal follow-up prevents assessment of whether elevated WHtR in adolescence predicts hypertension in adulthood.

RELEVANCE OF THE STUDY

This study contributes to the limited but growing body of evidence on the utility of waist-to-height ratio as a cardiovascular risk screening tool in Indian adolescents, a population that has been relatively underrepresented in existing literature. Unlike conventional indices such as BMI, WHtR captures central adiposity and has demonstrated a stronger association with cardiometabolic risk factors; this study provides empirical validation of this relationship in a North Indian school-going population. The finding that adolescents with WHtR ≥0.5 have approximately 2.3-fold higher odds of elevated systolic blood pressure adds quantitative evidence supporting the clinical utility of this universal cut-off in a low- and

middle-income country context. By demonstrating WHtR's predictive value for blood pressure elevation using a comparatively large sample (n=800) with a balanced gender distribution, this study strengthens the case for its adoption in routine pediatric health screening in resource-constrained settings. The results highlight the need for early preventive cardiovascular health interventions during adolescence in India and support the integration of WHtR into national school health programs and pediatric guidelines, thereby adding practically actionable knowledge to the existing literature.

Authors Contribution

All authors have contributed equally.

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Nil

Conflict of Interest

There are no conflicts of interest.

Declaration Of Generative AI And AI Assisted Technologies In The Writing Process

During the preparation of this work, the authors used Quillbot for paraphrasing the text and Claude AI for improvement in the language and grammar of the draft manuscript.

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