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ORIGINAL ARTICLE

Determinants of Waist-to-Height Ratio and Its Relation to Hypertension among School Children in India: A Multicenter Study

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Abstract

Objective To study the factors associated with waist-to-height ratio (WHtR) among school children aged 5–15 y and its association with hypertension.

Methods In this cross-sectional study, data on background characteristics, socioeconomic status (SES), anthropometric parameters, and blood pressure were obtained from school children from three states of India. WHtR ≥ 0.5 was defined as obesity and hypertensives were defined based on Fourth Report criteria. Descriptive statistics were applied and multiple linear regression was done to identify factors associated with WHtR. A receiver operating characteristics (ROC) analysis was used to evaluate the predictive ability of WHtR to predict hypertension

Results The mean WHtR among the 12,068 students was 0.40 (± 0.05) and it showed a U-shaped distribution with age with trough at 10 y of age for both genders. Mean WHtR was higher among residents of Manipur, among boys and hypertensives. WHtR was positively associated with weight > 30 kg, male gender, schools with high SES, Manipur and Goa region, and negatively associated with age > 10 y. The area under the ROC curve of WHtR for diagnosis of hypertension was low 0.544 (95% CI 0.532, 0.556).

Conclusion There is a nonlinear relation between age, gender, and WHtR, which varies by geographical region and HT. This would need to be kept in mind while using it to identify obesity in children, though its discriminant value for hypertension is low.

Keywords Childhood obesity · Waist-to-height ratio · Hypertension

Introduction

Increasing prevalence of childhood obesity is one of the emerging public health challenges globally. Obese children stay obese in adulthood and are at a higher risk of cardiovascular, metabolic, endocrine, dermatologic, neurologic, renal, pulmonary, gastrointestinal, musculoskeletal, and psychosocial disorders [1–3].

Abdominal obesity is one of the strong predictors of hypertension and metabolic syndrome, and hypertension during adolescence is a powerful predictor of adult hypertension [4]. Among adolescents (aged 10–19 y), the prevalence of abdominal obesity range from 3.8% to 51.7% in low- and middle-income countries and from 8.7% to 33.2% in developed countries [5]. Recent systematic review and metanalysis from India documented childhood overweight and obesity prevalence as 19.3% [6].

Childhood obesity and its consequences can be prevented if early detection is practiced through school-based screening [7, 8]. Available indices for obesity include body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). Both, the choice of indicator and its cutoff pose a problem in this age group.

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Key challenges in operationalizing a school-based screening system are measurement of hip which needs privacy, availability of exact age group in many developing countries, and age-specific cutoffs to define obesity.

Studies have documented that WHtR, with a cutoff of 0.5, can be used for defining obesity in children 6 y and above, independent of age, sex, and ethnicity [9]. WHtR has demonstrated high degree of concordance with body fat and is reported to be a simple screening tool with a single cutoff. Moreover, it is reported to be convenient to measure and easy to interpret [10]. Studies have reported WHtR either as equivalent or superior to WC or BMI in predicting risk of cardiovascular disease, metabolic syndrome, hypertension, and diabetes [10, 11].

Till date, relatively fewer studies in India have explored utility of WHtR as a screening tool among school children for obesity [2, 12] and studied its association with hypertension [13, 14]. The primary objective of the study was to study the distribution and determinants of obesity using WHtR and the secondary objective was to study its relation to hypertension among school children in India.

Material and Methods

Data from a cross-sectional study conducted in primary and secondary schools in three states of India (Goa, Haryana and Manipur) as a part of rheumatic heart disease screening program were analyzed. The methodology of the main study along with details of anthropometry and blood pressure measurement is already published [15, 16]. For the present study, apparently healthy children aged 5–15 y from three sites were included ($N = 12{,}068$).

The anthropometric data were obtained by trained field investigators using standard protocols for height in centimeters, weight in kilograms, and waist circumference in centimeters. Weight was measured by analogue weighing scale, height by drawing scale on a flat vertical surface, and waist was measured by an inch tape around the waist. Blood pressure was measured by using oscillometric instrument in Haryana, and aneroid instrument was used to measure BP in Manipur, and mercury sphygmomanometer was used in Goa.

From the available data, BMI and WHtR were calculated. The cutoff for obesity was taken as WHtR ≥ 0.5 [17]. The Fourth Report criteria were used to define hypertensives [18]. Each school was assigned a socioeconomic status (lower, middle, and high) depending on the type of the school and development of the area, where school was located and all students of that school were given that label.

Descriptive statistics were calculated in SPSS version 17. The data were presented as mean (SD) or number (%), and prevalence is reported with 95% CIs. A $p < 0.05$ was considered as statistically significant. Pearson correlation coefficient was used to study the association of WHtR with age, weight, and BMI. The independent variables were age, BMI, gender, socioeconomic status, and regions. All the significant independent variables on univariable regression (p value < 0.2) that were associated with WHtR were used to build the final multiple linear regression model to highlight the predictor variables (p value < 0.05). Appropriate cutoff points of WHtR, BMI, and WC for hypertension were selected using receiver operating characteristics (ROC) analysis. The discriminating power of WHtR, BMI, and WC for hypertension were expressed as area under the curve (AUC). The values for cutoff points were derived from ROC curves by using the lowest value for $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$ [19].

Results

Among 12,068 participants, 66.6% were children aged 10–15 y and mean age was 10.8 ± 2.8 y. Among them 56.2% were boys and 54.8% attended schools graded as belonging to high socioeconomic status.

Table 1 shows the distribution of different parameters across gender in the study sample. On an average, boys had higher mean values for weight, height, WC, and WHtR than girls whereas mean values for BMI was higher among girls ($p < 0.05$).

The association of WHtR with age, gender, weight, BMI, study sites, and SES were studied. The mean WHtR showed a U-shaped distribution across age and a weak negative correlation was observed between WHtR and age ($r = -0.053$, $p = 0.0005$). Across both genders, WHtR decreased from 5 to 10 y. However, after the age of 10 y, among the boys, WHtR increased till 13 y of age and then it decreased again. Among girls in this age group, WHtR showed a decrease till 12 y and then continued to increase till 15 y (Fig. 1).

WHtR and weight were positively correlated ($r = 0.261$, $p = 0.0005$). After attaining weight of 30 kg, WHtR increased with increase in weight. This shows that after a threshold weight of 30 kg, all parameters such as WHtR, WC, or BMI increase. Hence, a single cutoff for WHtR may not have a good discriminant value for those who weigh 30 kg and above (Fig. 2).

Mean WHtR was higher among residents of Manipur (0.434 ± 0.03), those who attended middle SES schools (0.433 ± 0.51) among boys (0.402 ± 0.05) and hypertensives (0.408 ± 0.057). (Supplementary Fig. S1).

While studying the relationship of WHtR with different centers, a higher WHtR among students for Goa and Manipur was observed, as compared to Haryana (Table 2).

With one-way ANOVA, mean values for age, height, weight, WC, BMI, and WHtR were found to be statistically different across different sites ($p < 0.05$). The mean WHtR was

Table 1 Anthropometric characteristics of school students ($N = 12,068$)

Variable	Total ($N = 12,068$) Mean (SD)	Boys ($N = 6784$) Mean (SD)	Girls ($N = 5284$) Mean (SD)	*p* value
Age (y)	10.8 (2.8)	10.8 (2.8)	10.7 (2.8)	0.111
Weight (kg)	32.4 (12.0)	32.7 (12.3)	32.1 (11.5)	0.004
Height (cm)	137.3 (16.5)	138.2 (17.3)	136.1 (15.4)	0.000
Waist circumference (cm)	55.0 (9.7)	55.5 (9.9)	54.3 (9.4)	0.000
BMI (kg/m^2)	16.6 (3.1)	16.5 (3.0)	16.7 (3.2)	0.000
Waist-to-height ratio	0.401 (0.05)	0.402 (0.05)	0.400 (0.05)	0.036

highest among students belonging to Manipur (0.434) followed by Goa (0.0433) and lowest was in Haryana (0.382). Across gender, mean values for age (except among boys), height, weight, WC, BMI, and WHtR were found to be statistically different across different sites.

With one-way ANOVA, mean values for age, height, Wt, WC, BMI, and WHtR were found to be statistically different across different SES ($p < 0.05$) (Table 3).

Students attending schools with middle SES had higher WHtR (0.43) as compared to lower (0.38) and high socio-economic status (0.39).

Across gender, mean values for age (except boys), height, Wt, WC, BMI, and WHtR were found to be statistically different across different SES both, among boys and girls ($p < 0.05$). The BMI and WHtR were positively correlated with each other ($r = 0.56$, $p = 0.0005$).

Regression analysis was done to study the determinants of WHtR in students. The adjusted R^2 for the overall model was 27.6%. WHtR was positively associated with weight > 30 kg, male gender schools with high SES, Manipur and Goa region, and negatively associated with age > 10 y ($p = 0.0005$) (Supplementary Table S1).

The prevalence of obesity (WHtR ≥ **0.5)** across age, gender, SES of attending schools, and sites were further studied. A total of 4.6% (95% CI: 4.2–4.9) school students with 4.5% boys and 4.8% girls were obese. Obesity was more prevalent among students with middle SES and those who were resident of Goa (Supplementary Table S2).

Additionally, the association of HTN with WHtR were also studied. Among hypertensives, mean WHtR was significantly different for both genders $t\ (2918) = 2.732$; $p = 0.006$.

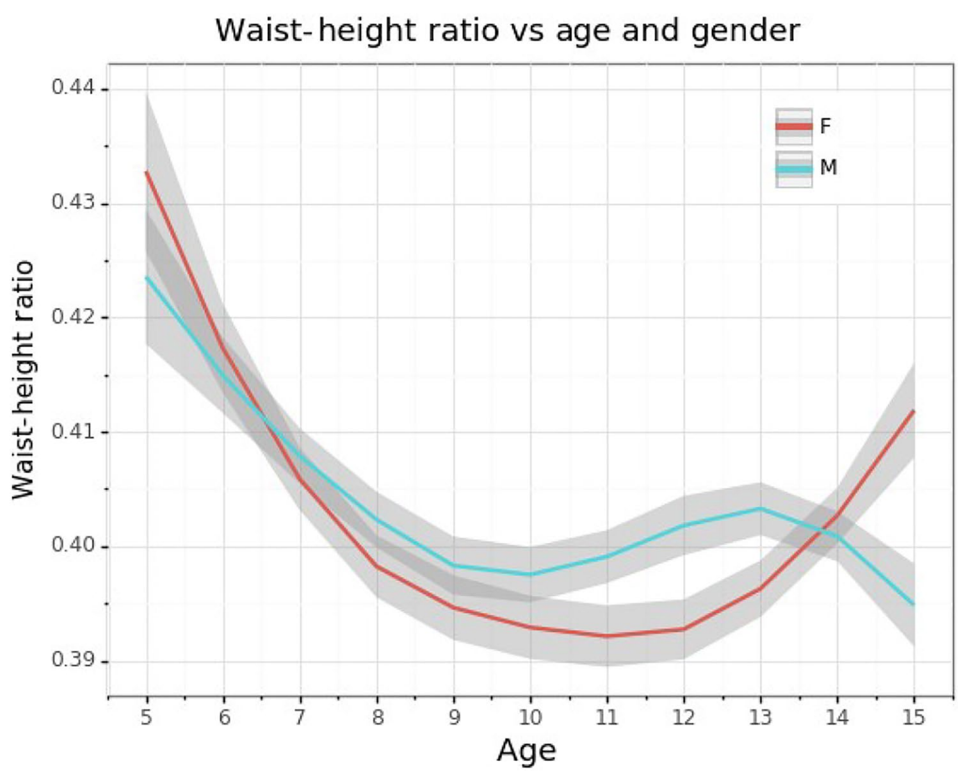

Fig. 1 Relationship of mean waist-to-height ratio with age across gender

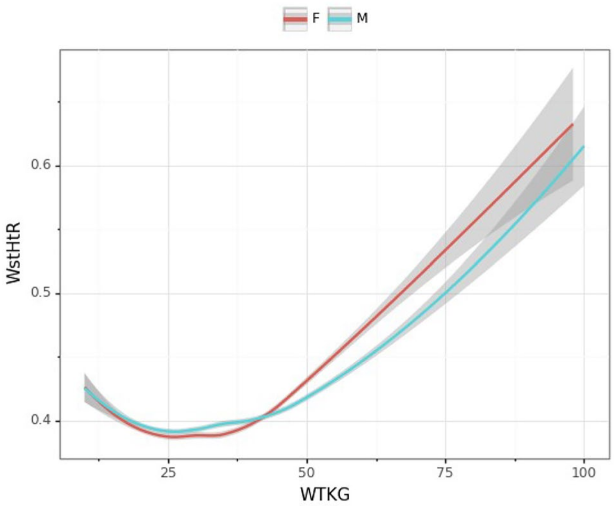

Fig. 2 Relationship of waist-to-height ratio with weight across gender

It showed that all three parameters have low discriminating power and have similar area under the ROC curve (AUC). The AUC for WHtR was 0.544, 95% CI (0.532, 0.556). Similarly, for BMI and WC, the area under the ROC curve for BMI and WC was 0.559, 95% CI (0.547, 0.571) and 0.517, 95% CI (0.504, 0.529), respectively. The cutoff points 0.39 for WHtR provided 53.5% sensitivity and 52.0% specificity for detecting hypertension.

Discussion

The data from a previous research were reanalyzed to explore determinants of waist-to-height ratio among school students aged 5–15 y.

This is the first study from India where distribution of WHtR with age, weight, gender, regions, and SES of area/schools is studied. Mean WHtR showed a U-shaped distribution with age where it dereased till 10 y of age and showed an increase beyond that across both genders. This could be due to the effect of onset of puberty. Similar to other studies in Hong Kong and Brazil, a higher mean WHtR among boys [20, 21] was observed. The Hong Kong study reported a decrease in WHtR with age up to 14 y and a little change beyond 14 y, whereas study from Brazil reported a highest mean WHtR at 11 y of age in boys and 15 y of age in girls. Contrary to this, a study among school children aged 6–12 y from Thailand reported a little change in WHtR with age, and considered it to be relatively age-independent measure of central obesity [22]. Additionally, an increased mean WHtR after attaining weight of 30 kg was found in schools with middle SES and among students from Manipur.

On regression analysis, WHtR was positively associated with weight > 30 kg, male gender, schools with high SES,

Table 2 Distribution of variables across different sites and gender ($N = 12{,}068$)

Mean values	Total Mean (SD)			*F* test (*p* value)	Boys Mean (SD)			*F* test (*p* value)	Girls Mean (SD)			*F* test (*p* value)
	Goa	Haryana	Manipur		Goa	Haryana	Manipur		Goa	Haryana	Manipur	
Age (y)	11.1 (2.7)	10.5 (2.8)	11.6 (2.7)	149.15 (0.0005)	11.0 (2.7)	10.5 (2.8)	11.7 (2.6)	2.45 (0.086)	11.0 (2.7)	10.4 (2.8)	11.4 (2.7)	28.39 (0.0005)
Height (cm)	138.6 (15.8)	136.4 (16.8)	139.1 (16.2)	30.05 (0.0005)	139.01 (16.5)	137.2 (17.2)	140.8 (17.0)	29.11 (0.0005)	138.2 (14.9)	135.2 (15.7)	137.0 (14.9)	10.66 (0.0005)
Weight (kg)	32.6 (12.3)	31.3 (11.7)	36.3 (12.1)	164.01 (0.0005)	32.3 (12.1)	31.6 (12.0)	37.0 (12.4)	61.20 (0.0005)	32.9 (12.4)	30.7 (11.0)	35.4 (11.4)	9.88 (0.0005)
Waist (cm)	60.1 (9.7)	52.2 (9.1)	60.2 (8.0)	1097.50 (0.0005)	60.1 (9.9)	53.0 (9.6)	60.6 (7.7)	214.91 (0.0005)	59.9 (9.5)	50.9 (8.1)	59.7 (8.3)	255.16 (0.0005)
WHtR	0.433 (0.05)	0.382 (0.05)	0.434 (0.04)	1508.47 (0.0005)	0.43 (0.05)	0.38 (0.05)	0.43 (0.03)	228.39 (0.0005)	0.43 (0.05)	0.37 (0.04)	0.43 (0.04)	324.36 (0.0005)
BMI (kg/m^2)	16.4 (3.5)	16.2 (3.0)	18.1 (2.8)	374.74 (0.0005)	16.1 (3.1)	16.1 (2.9)	18.0 (2.6)	73.98 (0.0005)	16.3 (3.7)	16.2 (3.0)	18.2 (3.0)	24.99 (0.0005)

Table 3 Distribution of variables across different socioeconomic status and gender ($N = 12{,}068$)

Mean values	Total Mean (SD)			F test (p value)	Boys Mean (SD)			F test (p value)	Girls Mean (SD)			F test (p value)
	Lower SES	Middle SES	High SES		Lower SES	Middle SES	High SES		Lower SES	Middle SES	High SES	
Age (y)	10.9 (2.8)	11.1 (2.7)	10.6 (2.8)	18.36 (0.0005)	10.8 (2.8)	11.0 (2.7)	10.8 (2.8)	2.45 (0.08)	11.0 (2.7)	11.0 (2.7)	10.4 (2.8)	28.39 (0.0005)
Height (cm)	135.6 (16.1)	138.6 (15.8)	137.8 (16.9)	25.75 (0.0005)	135.6 (16.7)	139.0 (16.5)	139.2 (17.6)	30.07 (0.0005)	135.7 (15.3)	138.2 (14.9)	135.6 (15.6)	10.66 (0.0005)
Weight (kg)	30.7 (10.6)	32.6 (12.2)	33.3 (12.5)	54.43 (0.0005)	30.3 (10.7)	32.3 (12.1)	33.9 (12.9)	61.20 (0.0005)	31.1 (10.4)	32.9 (12.4)	32.4 (11.8)	9.88 (0.0005)
Waist (cm)	52.3 (7.8)	60.1 (9.7)	54.9 (10.1)	423.59 (0.0005)	52.8 (7.6)	60.1 (9.9)	55.5(10.4)	214.91 (0.0005)	51.7 (7.9)	59.9 (9.5)	54.0 (9.5)	255.16 (0.0005)
WHtR	0.38 (0.04)	0.43 (0.05)	0.39 (0.05)	506.76 (0.0005)	0.39 (0.04)	0.43 (0.05)	0.39 (0.05)	228.39 (0.0005)	0.38 (0.04)	0.43 (0.05)	0.39 (0.05)	324.36 (0.0005)
BMI (kg/m^2)	16.1 (2.6)	16.3 (3.4)	16.9 (3.2)	77.82 (0.0005)	15.9 (2.4)	16.1 (3.1)	16.8 (3.1)	73.98 (0.0005)	16.3 (2.7)	16.6 (2.7)	17.0 (3.4)	24.99 (0.0005)

Manipur and Goa region, and negatively associated with age > 10 y.

This difference in WHtR across gender could be due to physical changes during adolescence and point out the need for a different cutoff. Further a regional difference is observed in WHtR and can be due to differences in WC and height differences. These differences in anthropometry measures between sites could be due to racial, genetic as well as lifestyle differences in the studied population. A declining trend among students attending schools with low SES was observed, which explains the lower nutritional status, and hence, low WC and height. Similarly, a study from Pakistan among students aged 5–12 y reported a higher WHtR in urban areas with high SES and high parental education [23].

Countries such as Brazil, Thailand, China, etc. have developed age- and gender-specific etc. standards/percentiles [21, 22, 24]. Whereas from India, a single study had published WHtR references for urban south Indian children aged 3–17 y [25]. This study had also documented that the proportion of children with WHtR ≥ 0.5 decreases with age across gender and 50% children with WHtR > 0.5 were in the younger age group (3–6 y). However, findings from this study can only be applicable to urban children. The present study highlights that WHtR varies with age and gender, and optimal cutoffs may be required to take into consideration these differences. Additionally, dual energy X-ray absorptiometry (DEXA) should be used to as a reference and optimal cutoff for WHtR should be finalized for obesity and overweight. However, in absence of an optimal cutoff and in light of available evidence, the authors suggest that WHtR ≥ 0.5 can still be used for school-based screening of central obesity.

Similar to other studies, WHtR (cutoff WHtR ≥ 0.5) has been used as the index for measuring central obesity [26, 27]. It should be used in preference to BMI as WHtR measures central obesity, which is equivalent or superior to BMI for predicting risk of cardiovascular disease, metabolic syndrome, hypertension, and diabetes. Among 12,068 students aged 5–15 y, 4.6% were obese. Higher prevalence was documented in among students aged 10–15 y, who were boys, who belong to Goa, and in schools with Middle SES. A study by Patil et al. among students aged 9–15 y in Mumbai reported WC and WHtR as robust indicators for central obesity [2]. In their study, they reported obesity prevalence as high as 26.3% (cutoff WHtR ≥ 0.5). The cited reasons for higher prevalence include sampling bias as the students mainly belonged to urban middle-class communities, and accuracy of measurement.

To elaborate the issues of optimal cutoff of WHtR for obesity, a study from Kerala by Panjikkaran, proposed WHtR cutoff as 0.48 with larger AUC (0.827) and higher sensitivity (63.7%) than that with WHtR as 0.50 with smaller AUC

(0.637) and lower sensitivity (37.6%) for overweight/obesity [12]. Most of the studies were done on population aged 6 y and above. The WHtR as a tool for obesity has not been used or validated among preschool children. If WHtR > 0.5 is taken as the cutoff for obesity, a slightly lower obesity prevalence as 4.2% (0.4% difference in obesity prevalence) is obtained.

Similar to the present study, the study by Mishra et al. from Banglore reported a comparable and low discriminating ability ($0.5 < AUC < 0.7$) of all the three parameters (WHtR, BMI, and WC) for hypertension [14]. The sensitivity and specificity of detecting hypertension were low in the present study (WHtR, Sn: 53.5%, Sp: 52.0%). Similarly, a systematic review and meta-analysis reported low-pooled sensitivity (43%) and moderate-pooled specificity (77%) of WHtR for detecting HTN [28].

Contrary to this, another study among Lithuanian adolescents (aged 12–15 y) reported a strong association of BMI and WC with hypertension as compared to WHtR [29]. Another study from Tehran reported BMI as a better predictor of hypertension [30].

The strength of the present study is that it is a multisite study with a representation from Goa, Manipur, and Haryana and the results from this study are generalizable. The limitations of the study are that a linear regression with WHtR as dependent and age as an independent variable was run, although they showed a U-shaped relation with each other; the blood pressure measurement was taken on the same day and no follow-up was made to confirm hypertension. The information on dietary habits and physical activity that could have affected WHtR was also not collected.

Conclusion

There is a nonlinear, relation between age, gender, and waist-to-height ratio. Weight, geographical region, and hypertension are also related to WHtR.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12098-021-03879-2.

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Declarations

Ethics Committee Approval The ethical approval was obtained from the Institute Ethics Committee at all three sites.

Informed Consent It was obtained from each school principal as well as the parents

Conflict of Interest None.

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