RESEARCH PAPER

Waist-to-Height Ratio as an Indicator of High Blood Pressure in Urban Indian School Children

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Objectives: To examine the utility of waist-to-height ratio to identify risk of high blood pressure when compared to body mass index and waist circumference in South Indian urban school children.

Design: Secondary data analysis from a cross-sectional study.

Settings: Urban schools around Bangalore, India.

Participants: 1913 children (58.1% males) aged 6-16 years with no prior history of chronic illness (PEACH study).

Methods: Height, weight, waist circumference and of blood pressure were measured. Children with blood pressure ≥90th percentile of age-, sex-, and height-adjusted standards were labelled as having high blood pressure.

Results: 13.9% had a high waist-to-height ratio, 15.1% were overweight /obese and 21.7% had high waist circumference. High obesity indicators were associated with an increased risk of high blood pressure. The adjusted risk ratios (95% CI) of high systolic blood pressure with waist-to-height ratio, body mass index and waist circumference were 2.48 (1.76, 3.47), 2.59 (1.66, 4.04) and 2.38 (1.74, 3.26), respectively. Similar results were seen with high diastolic blood pressure.

Conclusion: Obesity indicators, especially waist-to-height ratio due to its ease of measurement, can be useful initial screening tools for risk of high blood pressure in urban Indian school children.

Keywords: *Anthropometry, Hypertension, Obesity, Risk*.

High blood pressure, *i.e.* either high systolic blood pressure (SBP) or high diastolic blood pressure (DBP), is increasingly being reported in children [1-4]. Indian children are more susceptible to obesity-mediated high blood pressure [5-7]. Also, as elevated blood pressure tracks over time; children with high values are at a higher risk of developing hypertension in adulthood [8].

Blood pressure measurements in children require trained professionals to carry out and interpret the readings [9]. As this may be difficult in a school-setting, the use of anthropometry, carried out as part of a routine school physical examination, would be beneficial to identify children at risk of high blood pressure. Commonly used obesity indicators such as waist-to-height ratio (WHtR), body mass index (BMI) and waist circumference (WC) have been examined as alternate indicators of HBP in adults and children [10-14]. WHtR has been found to be a simple, easy and accurate index, suitable as a screening tool for obesity in children and adolescents from India [15]. However, studies on the association between WHtR and childhood high blood pressure [14,16,17], are unavailable for Indian children. The aim of the present study was to examine the association of WHtR, BMI, and WC with high blood pressure in urban children aged 6 to 16 years from Southern India.

METHODS

Children in this cross-sectional observational study were recruited as part of an ongoing cohort study, *viz*. Pediatric Epidemiology and Child Health (PEACH) [15]. Convenient samples of private schools in Bangalore, which cater to urban middle-class families, were selected based on permission to carry out the study during school hours. Healthy children between the ages of 6 to 16 years with no significant clinical history or any chronic illnesses were eligible to participate in the study. Children recruited from four schools during the PEACH study period (August 2011 to March 2013), were considered for inclusion in the present study. The study was approved by the Institutional Ethical Review Board at St. John's Medical College, Bangalore. Of the 2495 students who were contacted, written informed consent was obtained from either a parent/guardian of 1970 children. From these, 1913 children who had two readings of BP and all anthropometric measurements (height, weight and waist circumference) were included for the current analysis. A sample size of 1010 children was sufficient to examine an increased odds of 2.28 for hypertension among children with WHtR ≥0.5 when compared to those with WHtR <0.5, with 5% level of significance and 80% power [14].

Demographic data on date of birth, medical history, birth weight, parental education, occupation, income, parental height and weight were collected from the parents. The questionnaires used in this study were used in the previous PEACH study [15], and have been pre-tested to ensure that both the children and parents understood all questions and provided reliable data. Comprehensive questionnaires capturing physical activity patterns, tuition time (hours per week), time spent in sedentary activities at home (watching television, playing computer games) and average sleep duration per night were completed by the parents of students below the 6th grade and by the students in the 6th grade and above. Physical activity patterns were assessed by asking about time spent playing games outside school and the type of sports in which the children regularly engaged.

Anthropometric measurements of body weight and height were performed by trained staff using standardized procedures [18]. Body weight was measured to the nearest 0.1 kg using a calibrated digital scale (Tanita, Tokyo, Japan); children were asked to remove their shoes and socks, and to change into light clothing. Height measurements were taken to the nearest 0.1 cm using a portable stadiometer (Seca 213, Germany); children were asked to remove shoes and socks. For measurement of WC, children were asked to remain in a standing position and measurements were taken using a non-stretchable tape during end-tidal expiration, exerting the same standard pressure on the tape at the midpoint of the lowest ribcage and the iliac crest [19]. WHtR was calculated as WC (cm) divided by height (cm) for all children. BP measurements were taken using a mercury sphygmomanometer as recommended in American Heart Association guidelines [9]. Measurements were taken in a quiet room while the child was sitting with their arm resting on a table. Efforts were made to eliminate factors which may affect BP such as anxiety, crying or prior exercise. The average of two consecutive readings was used in the analysis. All BP measurements were taken by the same trained professional.

The different sports and games reported were classified into three categories (mild, moderate, vigorous) based on the metabolic equivalent (MET) score [20]. Activities below 3 METS were considered as light, 3-6 MET were considered as moderate, and greater than 6 METS as vigorous. The total duration of physical activity (in MET hours) was then calculated by multiplying the total duration of games played in each category with its average MET score value. Time spent watching television and time spent on the computer/video games was grouped together as screen time.

Statistical analysis: Child's age-and-sex specific height percentiles were computed according to the CDC criteria [21]. BP percentiles for each child were calculated according to National Heart Lung and Brain Institute guidelines [22] based on the child's age, sex, and height percentile. All children with BP ≥90th percentile for SBP and ≥90th percentile for DBP were classified as high SBP or high DBP, respectively. HBP was defined as either high SBP or high DBP. WHtR Z scores were calculated using age-and-sex specific data for South Indian children [15]. Children with a WHtR< 0.5 were defined as normal, whereas a WHtR ≥0.5 was labelled as high WHtR [11]. All children were also classified into 3 categories viz. underweight, normal, and overweight/obese, based on their BMI according to the age- and sex-specific cut-offs recommended by IOTF [23]. WC Z scores for all children were calculated using age- and sex- specific data available for South Indian children. Children with WC >75th percentile, i.e WC >0.67 Z score were considered to be at risk of HBP [15].

The discriminative capacity of BMI Z scores, WC Z scores and WHtR in their ability to determine high SBP and high DBP was examined and compared by plotting the Receiver Operating Characteristic (ROC) curves for each indicator and comparing the area under the curve (AUC). The AUC of WHtR was compared with that of BMI and WC using a previously described method [24].

The associations of WHtR Z score, BMI Z score and WC Z score with systolic and diastolic BP percentiles were examined using linear regression. Multi-variable models were constructed including all potential covariates at $P<0.10$ in the bivariable analysis. Crude and adjusted regression coefficients (β) along with corresponding 95% confidence intervals (95% CI) are reported for the association of BP percentiles with WHtR, BMI, and WC.

The association of high WHtR, overweight/obese BMI and high WC with high systolic and diastolic BP was examined using log binomial regression. Multivariable log binomial models were constructed with the same covariates as mentioned above. Crude (RR) and adjusted risk ratios (ARR) are reported along with 95% CI. Each of these obesity indicator was considered as independent variable in separate regression analyses.

Two-sided *P*-values <0.05 were considered statistically significant. Statistical analyses were performed using SAS program (version 9.2; SAS, Cary, N.C., USA) and SPSS (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Log binomial regression analysis was performed using the PROC GENMOD program in SAS.

RESULTS

A total of 1913 children (1111 males) were analyzed. Mean age of the children was 12 years. The proportion of children with high SBP and high DBP were 8.0% (108) and 2.7% (51) respectively. High WHtR was observed in 14.1% (269) of the children, while 15.1% (289) were overweight/obese and 21.7% (415) had a high WC. WHtR was strongly correlated with BMI Z score and WC percentiles (r=0.89 and 0.74, respectively, both *P*<0.001). ***Table*** **I** depicts the demographic, behavioral and anthropometric characteristics along with the BP of the children in the study.

The multivariable linear regression model adjusted for the following factors based on their significance in univariable analysis with either/both BP percentiles: maternal BMI (*P*=0.091 DBP), screen time (*P*<0.001 SBP, *P*=0.001 DBP), tuition time (*P*=0.021 SBP, *P*=0.040 DBP), physical activity (*P*=0.004 SBP, *P*=0.019 DBP) and sleep duration (*P*=0.010 DBP). Similarly, log binomial regression analysis adjusted for age, sex and sleep duration (*P*<0.001 SBP) based on univariable *P* values. Age and sex were included in all models regardless of *P* value as they directly affect BP.

As shown in ***Table*** **II,** the AUCs of WHtR, BMI and WC with respect to their ability to detect either high systolic BP or high diastolic BP were statistically significant (*P*<0.001). The AUC of WHtR for high systolic BP was slightly higher (*P*=0.025) than that of WC but was comparable with that of BMI. The AUCs were all comparable with each other for high diastolic BP. Multiple variable linear regression of systolic BP percentiles with Z scores of WHtR, BMI and WC showed that the regression coefficients were comparable for the three obesity indicators (β=4.93, 4.29 and 3.76, respectively). Similarly the regression coefficients were comparable in the analysis of diastolic BP percentile (β=2.56, 2.35 and 2.32, respectively) (***Table*** **III**).

The increased risk of high BP with high WHtR was confirmed using multivariable log binomial regression with ARR: 2.48 (95% CI: 1.76, 3.47) and ARR: 3.38 (95% CI: 1.81, 6.30) for high systolic BP and high diastolic BP respectively, adjusting for age, sex and sleep. The risk of high BP was comparable for all three obesity indicators (***Table*** **IV**). The sensitivity and specificity of WHtR for high systolic and diastolic BP was 27.4% and 88.2%, and 35.3% and 86.5%, respectively. The sensitivity of BMI and WC for high systolic BP was

TABLE I DEMOGRAPHIC, ANTHROPOMETRIC AND BEHAVIORAL CHARACTERISTICS OF CHILDREN (*N*=1913) IN THE STUDY

Characteristics	*Mean (SD)*
Population Characteristics	
Age (y)	12 (3)
#Male sex	1111 (58.1%)
Birth weight (kg)	3.0 (0.6)
Father's BMI (kg.m^{-2})	25.1 (5.3)
Mother's BMI (kg.m^{-2})	25.4 (6.7)
Anthropometry	
Height (cm)	144.9 (14.9)
Weight (kg)	38.5 (13.3)
Waist circumference Z score	-0.25 (1.28)
BMI Z score (kg.m^{-2})	-0.12 (1.25)
Waist-to-height ratio	0.4 (0.1)
Waist-to-height ratio Z score	-0.32(1.37)
Blood Pressure	
Systolic blood pressure (mm Hg)	108 (8)
Systolic BP percentile	59.9 (23.2)
#High systolic BP (≥90th percentile)	153 (8.0%)
Diastolic blood pressure (mm Hg)	60 (8)
Diastolic BP percentile	45.4 (22.3)
#High diastolic BP (≥90th percentile)	51 (2.7%)
Physical activity outside school	
*(MET hrs.week^{-1}) *n*= 1850	21(46)
*Screen time (hrs.week^{-1}) *n* = 1549	9(9)
*Tuition time (hrs.week^{-1}) *n* = 1647	3(12)
*Sleep duration (hrs.night^{-1}) *n* = 1587	8(2)

*#No.(%); *Median (IQR).*

TABLE II AUCS OF WAIST-TO-HEIGHT RATIO, BMI AND WAIST CIRCUMFERENCE FOR RISK OF HIGH SYSTOLIC OR DIASTOLIC BLOOD PRESSURE (BP) (*N*=1913)

Characteristics	*Area Under Curve (95% CI)*	
	High SBP	*High DBP*
Waist-to-height ratio	0.64 (0.59-0.68)	0.67 (0.59-0.75)
BMI Z scores	0.62 (0.57-0.67)	0.69 (0.61-0.76)
WC Z scores	0.60 (0.55-0.65)	0.65 (0.56- 0.73)

BMI: Body mass indes; WC: Waist circumference: SBP: systolic BP: DBP: diastolic BP.

TABLE III LINEAR REGRESSION ANALYSIS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE (BP) PERCENTILES WITH WAIST-TO-HEIGHT RATIO Z SCORES, BMI Z SCORES, WAIST CIRCUMFERENCE Z SCORES

	Systolic BP percentiles		*Diastolic BP percentiles*	
Anthropometry	*Unadjusted (n=1913)*	*Adjusted (n=1014)*	*Unadjusted (n=1913)*	*Adjusted (n=1014)*
Waist-to-height ratio Z scores	4.02 (3.21-4.83)	4.93 (3.92-5.95)	2.38 (1.59-3.18)	2.56 (1.50-3.63)
BMI Z scores	2.86 (2.10-3.61)	4.29 (3.30-5.27)	1.50 (0.78-2.23)	2.35 (1.33-3.38)
Waist circumference Z score	3.05 (2.25-3.86)	3.76 (2.71-4.80)	2.05 (1.28-2.83)	2.32 (1.25-3.40)

All values are regression coefficient (95% CI).

TABLE IV LOG BINOMIAL REGRESSION ANALYSIS OF HIGH SYSTOLIC AND HIGH DIASTOLIC BLOOD PRESSURE (BP) PERCENTILES WITH WAIST-TO-HEIGHT RATIO, BMI Z SCORES AND WAIST CIRCUMFERENCE Z SCORES.

	High systolic BP (≥90th percentile)			*High diastolic BP (≥90th percentile)*		
	n/N (%)	*Unadjusted (n=1913)*	**Adjusted (n=1587)*	*n/N (%)*	*Unadjusted (n=1913)*	**Adjusted (n=1587)*
Waist to height ratio (≥0.5)	42/269(15.6)	2.33(1.67-3.24)	2.48(1.76-3.47)	18/269(6.6)	3.36(1.92-5.88)	3.38(1.81-6.30)
BMI						
Underweight	28/478(5.9)	0.83(0.55-1.26)	1.27(0.84-1.93)	5/478(2.5)	0.41(0.16-1.06)	0.46(0.18-1.22)
Overweight/ obese	44/289(15.2)	2.15(1.53-3.04)	2.59(1.66-4.04)	17/289(5.9)	2.32(1.30-4.17)	2.61(1.38-4.92)
Waist circumference (> 0.67 Z score)	61/415(14.7)	2.37(1.74-3.21)	2.38(1.74-3.26)	26/415(6.3)	3.71(2.16-6.35)	3.88(2.13-7.06)

*All values are Risk Ratio (95% CI); *Adjusted for age, sex, and sleep.*

28.7% and 39.9%, and 33.3% and 50.1% for high diastolic BP. The respective specificity values were 86.1% and 79.9% for high systolic BP, and 85.4% and 79.1% for high diastolic BP.

DISCUSSION

Our results showed statistically similar AUCs for WHtR, BMI and WC in detecting risk of high BP, indicating similar discriminatory ability for all three obesity indicators. Similar results were seen with blood pressure percentile when considered as a continuum in linear regression. The risk ratio of high BP was increased for all three obesity indicators confirming the comparable discriminatory ability of WHtR, BMI, and WC to detect high BP.

When compared to other studies, the AUC of WHtR was comparable to that seen by Freedman, *et al.* [13], but was slightly lower than that by Kuba, *et al.* [16]. This difference may be due to higher prevalence of overweight /obese children in their study population (49.7%) when compared to ours (15.1%). In addition, the risk ratio is similar to the previously reported values in children aged 7-17 years having high BP [14].

Pediatric high BP is known to track over time, possibly resulting in adult hypertension [8]; hence, early identification and interventions to reduce BP must take place as early as possible. Measuring BP, albeit the ideal method to identify high BP, has certain difficulties. It requires trained personnel, appropriate cuff size of sphygmomanometer, and must be taken in quiet surroundings with a calm child; making routine school screening laborious, if not impossible. A simple screening tool to identify children with high BP is thus the need of the hour. Obesity indicators *i.e.* BMI, WC and WHtR can serve as a surrogate for high BP as they require only simple anthropometric measurements, which are a part of routine school physical examination. Although BMI and WC do not have a single cut-off which can be applied to all children, WHtR can be interpreted easily by well-trained staff with no medical background [11]. However, as WHtR is only a screening tool, all children identified with a WHtR ≥0.5 must be referred to a physician for confirmation and final diagnosis of high BP.

Some of the limitations of the present study were that all readings were taken on the same day and there was no follow-up to confirm hypertension. Additionally, since the dataset represents urban children attending schools in Bangalore, these results need to be tested in a more diverse setting, before they can be generalized to the

WHAT IS ALREADY KNOWN?

- Obesity is associated with high blood pressure and there is a rising incidence of both in children.

WHAT THIS STUDY ADDS?

- Waist-to-height ratio, waist circumference and body mass index have similar discriminatory ability in detection of risk of high blood pressure in Indian children.

population of children in India. WHtR has a low sensitivity, and thus some children may be missed by this initial screening tool. However, due to its ease of administration with only a tape measure, simplicity of measurement and application of a single cutpoint across all ages, we suggest it be used as a simple screening tool in Indian populations until a more sensitive tool can be found. Given the large sample size of this study, with little inter-observer variation in BP readings, and the consistency of results with available literature from other populations, it is reasonable to conclude that simple anthropometric measures may be used to initially screen school going children for risk of HBP in an urban Indian setting. The WHtR has the added advantage of being easy to calculate and interpret, and hence can be used widely during routine school physical examination.

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Contributions: PEM, LS, TT, RK, AVK: conceptualizing the study, analyzing data and writing the manuscript; CD, RB, CMM: analyzing data and writing the manuscript. AVK: will be the guarantor of the study. The final manuscript was approved by all authors.

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