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Arm Circumference to Height-ratio (AHtR): An Alternate Tool to Identify Overweight and Obesity in Children Aged 5-12 Years

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ABSTRACT

Background and Objective: Childhood obesity is one of the major national health concerns. World Health Organization (WHO) recommends Body mass index (BMI) as the standard epidemiological measurement of obesity. The BMI is not quite independent of stature, especially at the younger ages. Hence, an alternative tool like arm-circumference-to-height ratio (AHtR) is necessitated. The aim of this study was to evaluate the accuracy of AHtR as an alternate tool to identify overweight and obesity in children aged 5-12 years.

Methods: This study was conducted in the Pediatrics Out-Patient Department of a tertiary care teaching center over 12 months (June 2020-May 2021) in Puducherry, India. Children between 5-12 years were included using the convenience sampling method. Their height, weight and mid-upper arm circumference (MUAC) were noted. BMI, AHtR, BMI-z scores and MUAC-z scores were calculated. All variables were analyzed in SPSS 23.0. Receiver operating characteristic (ROC) curve analysis was served to identify the age and gender-specific AHtR cut-offs to identify overweight and obesity.

Findings: This study was conducted on 1169 children that 623 (53.2%) patient were boys. The accuracy levels of AHtR for obesity were determined by area under curve (AUC) which was 0.962 for boys (cut-off=0.155) and 0.949 for girls (cut-off=0.175) between 5-12 years of age. BMI (kappa=0.605 and $p<0.01$) and MUAC (kappa=0.631 and $p<0.01$) significantly correlated with AHtR across all age groups.

Conclusion: AHtR is a simple, inexpensive, reliable, and accurate index to detect overweight and obesity in 5-12-year-old children. It serves as a useful alternative tool for BMI.

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Introduction

Intraventricular hemorrhage (IVH) Childhood overweight is defined as body mass index (BMI)≥85th percentile and obesity as BMI ≥95th percentile for the same age and gender in children above 2 years of age [1, 2]. The global prevalence of obesity has increased three-fold in the last 40 years with an estimated prevalence of about 671 million adults and 124 million children (5-19 years) [3]. In developing countries, lack of physical activity and increased consumption of High-Fat-Salt-Sugar (HFSS) food have been associated with an alarming rise in obesity [4, 5]. Indian children are found to have a high prevalence of obesity (5-9%) due to industrialization and urbanization. In Urban South India, 38% of adolescents (21% boys and 18% girls) are either overweight or obese [6].

International and Indian organizations like WHO, IOTF (International Obesity Task Force) and IAP (Indian Academy of Pediatrics) have recommended BMI-for-age as the ideal indicator for overweight and obesity for screening purposes [7-9]. Although BMI is a generally convenient measure, it lacks a theoretical foundation and may be compromised by ethnic, cultural or lifestyle differences. It is also clear that the BMI is not quite independent of stature, especially at the younger ages [10-12]. Moreover, BMI is greatly influenced by body proportions such that shorter-legged individuals have higher BMI values. The mid-upper arm circumference (MUAC) was found to be an alternate indicator for early detection of overweight and obesity by a few authors [13-16]. It is used as an alternative to chest circumference (CC) and waist circumference (WC) as it is independent of disruptions like respiratory movements and postprandial abdominal distension [2, 14].

MUAC is an age-gender-specific entity for children above 5 years of age with a wide variation among different ethnic groups. Though it is the best representation of body fat distribution, it doesn't always correlate with the growth rate of the child [17-19]. MUAC can be altered due to various causes that can defer their interpretation of the nutritional status. Thus, alternate measurements need to be used to measure both entities. Some studies have documented Arm-Circumference-to-Height-Ratio (AHtR) as an alternate, accurate and feasible tool [2, 20, 21]. AHtR may be advantageous as it is age-independent and weight-independent, thus requiring no scale calibrations daily. Moreover, AHtR is not sensitive to short-term weight fluctuations and requires less time and effort [21]. While predictive accuracy is a major concern in determining the suitability of anthropometric indicators in the clinical setting, cost-effectiveness and simplicity of the method for determining also can be crucial. Few studies have found that AHtR can reasonably predict cardiometabolic risk in adolescents having higher predictive accuracy than BMI [21]. Further research is needed to validate AHtR in predicting obesity and overweight in younger children.

The aims and objective of this study were to evaluate the accuracy of Arm Circumference-to-Height Ratio (AHtR) as an alternate tool to identify overweight and obesity in children aged between 5-12 years, and to determine optimal age and gender-specific cut-offs for AHtR to identify overweight and obesity in children aged between 5-12 years.

Methods

Design and participants

This prospective cross-sectional study was conducted in the Pediatric Outpatient Department of a Tertiary Healthcare Teaching Center over 12 months (June 2020 – May 2021) in Puducherry, India. Totally, 5-12-year-old children referred to our Outpatient Department for minor ailments were included in this study after obtaining consent from their parents. Children with significant physical deformities, chronic systemic illnesses, major congenital malformation, children on long-term medications and those who were unavailable for complete examination were excluded from our study.

Data collection

The convenience sampling method - a non-probability sampling technique- was used. Based on the mean difference [20] and keeping the confidence interval (CI) at 95%, sample size ratio of 1, power at 80% and alpha-error at 0.05, the calculated sample size was 1088 using EPI-INFO software.

The demographic and clinical details of the children were obtained by the principal investigator. Anthropometric measurements were obtained by the principal investigator along with trained staff nurses. Weight (in kg) was measured with light clothing on a digital scale with an accuracy of ±10 g. Height (in cm) was measured with no footwear, hair untied and maintaining frankfurt plane on a stadiometer measured to the nearest 0.1cm. MUAC (in cm) was measured using a non-stretchable measuring tape. Midway between the acromion process and olecranon process of the left arm was taken and documented as an average of two measurements. BMI (in kg/m2) and AHtR (MUAC in cm / Height in cm) were calculated and documented. Extended International Obesity Task Force (IOTF) BMI cut-offs were 25 and 30 for overweight and obesity, respectively [22]. Furthermore, BMI-z scores known as BMI- standard deviation (SD) scores are measures of relative weight adjusted for child age and sex. It can be calculated based on a child's age, sex, BMI and an appropriate reference standard. Similarly, MUAC-z scores are also considered as adjusted MUAC for child age and sex.

Statistical analysis

Statistical analysis was performed using SPSS-23.0. Continuous variables were reported as mean and standard deviation and categorical variables as frequency and percentage. To obtain the age-gender-specific cut-offs AHtR for overweight and obesity, Receiver Operating Characteristic (ROC) curve analysis was used.

Results

A total of 1196 school-age children were eligible for the study. After excluding 27 children due to lack of informed consent, a total of 1169 children were enrolled in this study (Figure 1). Out of them, 623 (53.2%) were males and 546 (46.7%) were females (Table 1). Sufficient anthropometric data were provided for the calculation of BMI z-scores, MUAC z-scores and AHtR z-scores for all children. The study population was divided into three age groups: 5-8 years, 9-10 years and 11-12 years. There was a significant relationship between BMI and AHtR (kappa=0.605 and p<0.01) for all three age groups. Moreover, MUAC significantly correlated with AHtR (kappa=0.631 and p<0.01) for all three age groups. On cross-tabulating BMI and AHtR z-scores, it was observed that they were all significantly correlated (50-81.3%) with a good correlation of 71.4% for >3 SD. Similarly, on cross-tabulating MUAC z-scores and AHtR z-scores, a significant correlation was obtained (50-4.6% with a good correlation of 84.6% for >3 SD. This proves that AHtR has a good potential similar to the gold standard measurements (BMI, MUAC) to identify overweight and obesity in school-age children. The accuracy of AHtR for identifying overweight and obesity amongst various age-gender-specific groups was good and comparable with BMI with cut-offs corresponding to 0.155 for overweight and 0.175 for obesity (Figures 2A-D).

The AHtR overweight cut-off of 0.155 had excellent AUC (0.952) in 5-8 years male, excellent AUC (0.938) in 5-8 years female, excellent AUC (0.948) in 9-10 years male, excellent AUC (0.951) in 9-10 years female, good AUC (0.890) in 11-12 years male and excellent AUC (0.954) in 11-12 years female. The AHtR obesity cut-off of 0.175 had an excellent AUC (0.969) in 5-8years male, excellent AUC (0.964) in 5-8 years female, excellent AUC (0.914) in 9-10 years male, excellent AUC (0.944) in 9-10 years female, excellent AUC (0.957) in 11-12 years male and excellent AUC (0.955) in 11-12 years female (Table-2).

Table 1. Demographic details of the children

Gender	Age (years)	Frequency	%	Mean age (years)	Mean weight (kg)	Mean BMI (kg/m^2)	Mean MUAC (cm)	Mean AHtR
Male	Total 5-8 9-10 11-12	623 361 164 98	53.2 30.8 14.1 8.3	8.0 (5-12)	25.5 (11.3-67)	10.17 (4.03-17.9)	18.93 (13.5-31)	0.15 (0.11-0.23)
Female	Total 5-8 9-10 11-12	546 313 148 85	46.7 26.8 12.7 7.2	8.0 (5-12)	25.6 (11.8-66)	10.28 (4.56-19.09)	18.70 (13.5-32.6)	0.15 (0.11-0.22)

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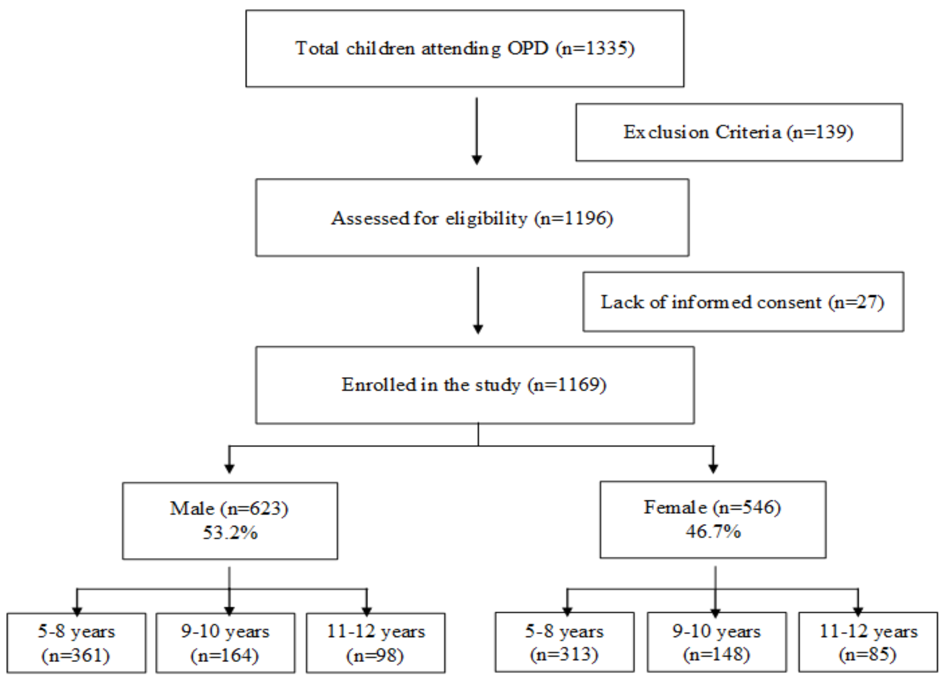
Table 2. Age-gender-wise AHtR cut-offs for identifying overweight and obesity

AHtR		Cut-off	AUC	Sensitivity (%)	Specificity (%)
5-12 years	Overweight	0.155	0.928	85.6	85.1
Male	Obesity	0.175	0.962	88.3	91.3
5-12 years	Overweight	0.155	0.931	83.0	88.4
Female	Obesity	0.175	0.949	87.8	88.3
5-8 years	Overweight	0.155	0.952	88.4	85.4
Male	Obesity	0.175	0.969	100.0	88.0
5-8 years	Overweight	0.155	0.938	82.2	90.6
Female	Obesity	0.175	0.964	94.1	86.0
9-10 years	Overweight	0.155	0.948	78.8	89.3
Male	Obesity	0.175	0.914	72.0	87.9
9-10 years	Overweight	0.155	0.951	87.6	84.4
Female	Obesity	0.175	0.944	91.7	88.7
11-12 years	Overweight	0.155	0.890	90.7	80.0
Male	Obesity	0.175	0.957	92.9	87.8
11-12 years	Overweight	0.155	0.954	97.8	85.1
Female	Obesity	0.175	0.955	100.0	80.0



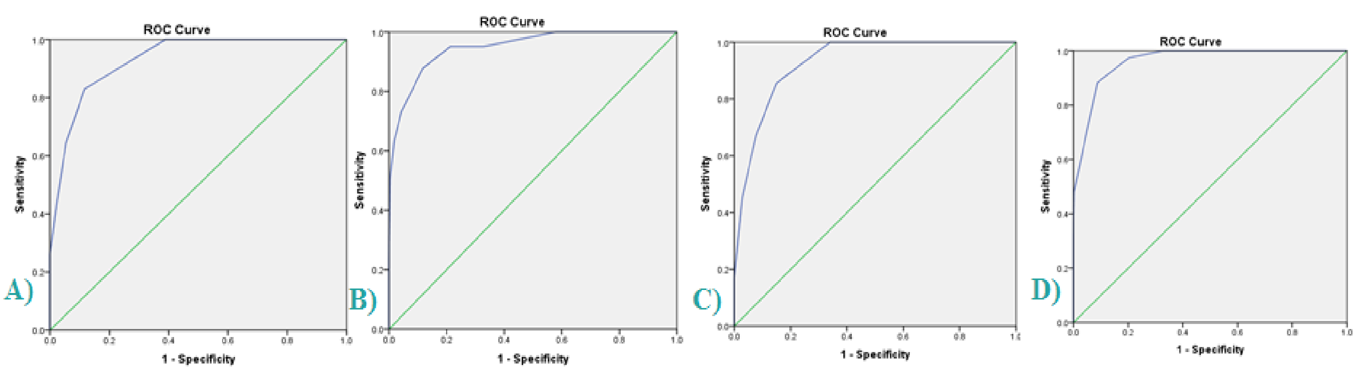


Figure 2. Area under the ROC Curve for 5-12 years.
AUC for: A) 5-12 years male/Overweight. B) 5-12 years male/Obese. C) 5-12 years female/Overweight. D). 5-12 years female/Obese

Discussion

This study has demonstrated that AHtR is a reliable index for overweight and obesity identification in South Indian school-age children with high AUC values. The cut-offs are age-independent and gender-independent, which makes it easier for calculation and implementation.

This study was conducted in one center on 623 male and 546 female eligible children (male: female- 1.14:1) which is similar to a study done by Sanguansak et al. in Thailand [20]. The mean age of boys included in the study was 8 years (5-12 years), the mean weight was 25.5 kg (11.3-67 kg) and the mean BMI was 10.17 kg/m2 (4.03-17.9 kg/m2). The mean age of girls included in the study was 8 years (5-12 years), the mean weight was 25.6 kg (11.8-66 kg) and the mean BMI was 10.28 kg/m2 (4.56-19.09 kg/m2). This was comparable with the study performed by Sanguansak et al., in which the mean age was 9.8 years (7-12.9 years), the mean weight was 33.2kg (13.4-116.7 kg) and the mean BMI was 17.98 kg/m2 (9.85-57.21 kg/m2).

The overall prevalence of obesity and overweight in the present study was 10.2% and 15.4%, respectively. The obesity prevalence 16% (more than that in our study) in the study by Sanguansak et al. The reason for the lesser prevalence of obesity in the current study could be attributed to more number of children visiting our hospital from rural areas. In India, the prevalence of obesity is significantly higher among urban residents compared to rural residents [23], which is in contrast to that in developed countries, where the prevalence of obesity is higher in rural areas.

In the current study, the optimal cut-off points for AHtR for the detection of obesity and overweight were 0.175 and 0.155. The accuracy for the diagnosis of overweight was excellent (AUC=0.928 in boys and 0.931 in girls). It also provided high sensitivity and specificity (sensitivity=85.6% in boys and 83% in girls, specificity=85.1% in boys and 88.4% in girls). The accuracy for diagnosis of obesity was excellent (AUC=0.962 for boys and 0.949 for girls). The sensitivity and specificity were also high (sensitivity=88.3% for boys and 87.8% for girls, specificity=91.3% for boys and 88.3% for girls). The results are comparable with other studies done by Lu et al. [2], Sanguansak et al. [20] and Jayawardene et al. [21] as shown in table 3.

The ongoing study discussed the use of AHtR as an alternative to BMI and MUAC in the evaluation of overweight and obese children in Puducherry, India. Although BMI is the best indicator for identifying overweight and obesity, it has its drawbacks including a poor indicator of body fat composition and distribution, influenced by body proportions and difficulty in interpreting the BMI-for-age charts. Other methods which can be used to measure body fat content and distribution such as dual X-ray absorptiometry are too expensive. Anthropometric measurements like MUAC and AHtR are considered alternatives to BMI for determining overweight and obesity and can be performed easily by parents or caretakers making their active involvement in the child's health status.

AHtR may be considered as an alternative tool to predict obesity because it has age-independent cut-offs. The fact that AHtR is adjusted by height which in turn strongly correlates with age, gives it an advantage over MUAC in the prediction of obesity using only peripheral fat measurement in the arm. It is also weight-independent and therefore is not affected by conditions causing short-term weight fluctuations.

Table 3. Comparison of AUC from various studies for accuracy of AHtR

AHtR	Our study (AUC)	Lu et al (AUC)	Sanguansak et al (AUC)	Jayawardene et al (AUC)
Overweight- Boys	0.928	-	0.975	-
Overweight - Girls	0.931	-	0.944	-
Obesity- Boys	0.962	0.956	0.929	0.722
Obesity - Girls	0.949	0.935	0.920	0.728

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Limitations of the study

The main limitation of the present study was that it included single-centered children from the rural land sub-urban areas of Puducherry, thus giving a low prevalence of obesity. Moreover, BMI, MUAC and AHtR were not compared with central obesity or body fat mass as the current concentrated only on general obesity. Another limitation was the lack of data on preschool children and adolescents.

AHtR can be studied in other regions of India and other ethnic groups to support this study. In future studies, this method will be applied to preschool children and adolescents for identifying overweight and obesity cut-offs. Furthermore, the cardiometabolic risk assessment can be studied by developing AHtR early prediction cut-offs for the said diseases.

Conclusion

It is concluded that AHtR is a simple, inexpensive, reliable and accurate index to detect overweight and obesity in school-age children. Cut-off points for AHtR to detect overweight and obesity were 0.155 and 0.175 for both genders, representing that it is age-independent. These values could be used as a reference for 5-12-year-old boys and girls.

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Ethical approval

This study was approved by Institutional Ethics Committee for human subjects (IECHS) AV/IEC/2020/077.

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Conflict of interest

The authors declare no conflicts of interest regarding the publication of this article.

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