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Use of mid-upper arm circumference and arm-to-height ratio to estimate overweight and obesity among girls aged 5-14 years

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KEYWORDS

mid-upper arm circumference, arm-to-height ratio, school-aged, BHCP girls

ABSTRACT

Overweight and obesity are major public health concerns that have plagued individuals worldwide pertaining to all age groups. The occurrence of this issue has been skyrocketing among children and adolescents since last few decades. Anthropometric indices such as body mass index (BMI) have always proved to be one of the best parameters in estimating overweight and obesity. However, alternatives such as mid-upper arm circumference (MUAC) and arm-to-height ratio (AHtR) have recently been observed to yield as potential tools in estimating overweight and obesity especially among children and adolescents. The current paper presented a cross-sectional study among Bengali Hindu Caste Population (BHCP) school-aged girls (5-14 years). Height, weight and MUAC were measured. BMI and AHtR were subsequently calculated. The presence of overweight and obese subjects was evaluated according to World Health Organization (WHO) 2007 population references of 5-19 years. Receiver Operating Characteristic (ROC) curve analysis was conducted to check the validity of MUAC and AHtR in determining overweight and obesity among age-groups (5-9 years and 10-14 years). The findings suggest that MUAC and AHtR have potential of proxy measure of overweight (including obesity) among the subjects.

Introduction

The prevalence of overweight and obesity among children and adolescents has become a daunting public health issue worldwide (Choukem et al. 2017). It is rather one of the most serious public health challenges of the 21st century. Reviews had elaborately pointed out several factors that trigger overweight and obesity among school-aged children (Sahoo et al. 2015; Xu and Xue 2016; Tran et al. 2019). The factors listed mainly include genetic, basal metabolic rate, dietary, activity level, environmental, socio-cultural, psychological, etc. Obesity among the children and adolescents has several short-term and long-term adverse effects on health (Reilly and Kelly 2011) as this significantly increases the risk of premature mortality, morbidity (e.g., diabetes, hypertension) and other related outcomes.

Studies regarding overweight and obesity among children and adolescents are of high-priority since overweight (and obese) children and adolescents have a greater tendency to become obese as adults compared to children with normal body mass index (BMI). Moreover, these adults face several challenges in exterminating few kilograms that they had gained during their early life (Pandita et al. 2016). Henceforth, pertinent early-stage diagnosis and treatment intervention for preventing overweight and obesity among this population is vital for curbing the risks of obesity-related complications.

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How do we distinguish between normal and overweight/obese children?

Since a child's BMI varies with age and sex, different age-specific cut-offs have been developed separately for both sexes. Children are termed as being overweight or obese if they have a BMI above the cut-off level for the given age and sex. In accordance with the age and gender-specific BMI criteria used by the World Health Organization (WHO 2007), obesity was defined as BMI > +2 standard deviation (SD) and overweight as BMI > +1 SD. Although there are different methods of pointing out overweight and obese children and adolescents, the sole purpose of mentioning this criterion is that the present study had utilized this criterion for data analysis.

Can mid-upper arm circumference (MUAC) do the same job?

As stated by the term itself, MUAC refers to the measurement of circumference of the mid-upper arm. It is the circumference of the right upper arm (conventionally, left upper arm) measured at the midpoint between the tip of the shoulder and the tip of the elbow (between the olecranon process and the acromium). MUAC measures the circumference of the upper arm which is made up of lean muscle and fat tissue (Brambilla et al. 2000) in addition to cross-section of bones and blood vessels. A recent observational, multinational cross-sectional study inferred that MUAC strongly correlated with adiposity indicators in both sexes (Chaput et al. 2017). Several other studies documented that MUAC has outperformed as an accurate yet simple and widely available indicator of overweight and/or obesity and its related complications in children and adolescents for clinical and surveillance applications (Ozturk et al. 2009; Ma et al. 2015; Kulathinal et al. 2016; Jaiswal et al. 2017; Mramba et al. 2017; Asif et al. 2018; Oyhenart et al. 2019; Talma et al. 2019). A growing body of evidences have also documented that ratio of mid-upper arm circumference-to-height (AHtR) is another accurate tool to screen childhood and adolescent obesity (Lu et al. 2014; Rerksuppaphol and Rerksuppaphol 2017; Jayawardene et al. 2018).

Why is the issue of overweight and/or obesity a major concern for girls?

Several studies concluded that the overall prevalence of overweight and obesity was more in girls compared to boys (Pangani et al. 2016; Desalew et al. 2017). This could be due to the reason that during and/or before the onset of puberty girls have the tendency to accumulate fat in their bodies (Meharda et al. 2017).

Keeping all the issues in mind, the present study aimed to frame the following objectives:

i. to assess the use of MUAC and AHtR for identification of overweight (including obese) children and adolescent girls;
ii. to find whether AHtR performed better than MUAC in discriminating overweight and obese subjects;
iii. to find the best cut-offs of MUAC and AHtR in discriminating overweight (including obese) subjects.

Materials and methods

Area of study

The present cross-sectional study was conducted among 1,000 school-going girls belonging to the Bengalee Hindu Caste Populations (BHCP), aged between 5-14 years and residing under Siliguri sub-division of Darjeeling district, West Bengal. Ethnically, the BHCP is a Bengali-speaking endogamous caste group of West Bengal and faithful to Hinduism. They are probably a blend of Dravidian and Mongoloid ethnic groups with a strain of Indo-Aryan blood among the higher caste groups (Das Chaudhuri et al. 1993). The study was conducted on four government secondary schools situated at the heart of Siliguri town of West Bengal, India. The selection of the schools was based on population strength, easy road connectivity and accessibility. The study was conducted in accordance with the ethical guidelines for human experiments, as laid down by the Helsinki Declaration of 2000 (Touitou et al. 2004).

Anthropometric measurements recorded

The anthropometric measurements were recorded following the standard techniques of Singh and Bhasin (1989). Height of the subjects was measured with the aid of anthropometer rod (GPM type, Galaxy Informatics, New Delhi) to the nearest 0.1 cm. Their body weight was recorded (with minimum clothing) using a portable weighing machine (Libra®, Edryl-India, Tiswadi, Goa) to the nearest 0.5 kg. MUAC was measured on the left arm of each subject placing Gullick measuring tape (Galaxy Informatics, New Delhi, India) midway between the tip of the acromion and the olecranon process to the nearest 0.1 mm. BMI and AHtR were calculated utilising the above records as follows:

BMI (kg/m^2) = weight in kilograms/(height in metres)^2

AHtR= MUAC (in cm)/height (in cm)

AHtR is unitless since it is a ratio.

A most commonly used indicator of precision or rather accuracy index (Perini et al. 2005) called Technical Error of Measurement (TEM) was utilized. For the calculation of intra-observer TEM, height, weight and MUAC were recorded from 50 BHCP school-going girls, other than those selected for the study. The measurements were taken thrice on each individual. The TEM was calculated by the formula of TEM [$TEM=\sqrt{(\sum D^2/2N)}$ where D=difference between the measurements and N= number of individuals measured] (Goto & Mascie-Taylor 2007).

The coefficient of reliability (R) which estimates the proportion of variance in a measured population (that is free from measurement error) was subsequently measured by the following equation:

$R= \{1-(TEM)^2/ SD^2\}$, SD=standard deviation of the measurements.

Very high values of R (> 0.975) were obtained for the intra-observer TEM analysis. All the values of R were appreciably higher than the accepted cut-off value of 0.95 as suggested by Ulijaszek and Kerr (1999). Hence, the anthropometric measurements recorded were considered to be reliable and reproducible and the TEM values were not incorporated for further statistical consideration.

Statistical Analysis

Evaluation of overweight and obesity was made in accordance with the age- and gender-specific (here, females) BMI-for-age z-scores (BAZ) using WHO Anthro-plus software. WHO Anthro-plus software is a computer program which converts anthropometric data into z-scores of the indices i.e., WAZ (Weight-for-age z-scores), HAZ (Height-for-age z-scores) and BAZ (BMI-for-age z-scores), taking age and sex into consideration using WHO 2007 population reference of 5-19 years. Girls whose BAZ <-5 and >5 were considered as outliers (in other words, whose z-scores exceeded flag limits) were excluded. Owing to such cases, 8 out of 1,008 were excluded. This yielded a final sample size of about 1,000. For further statistical analysis, Statistical Package for Social Science (IBM SPSS Statistics, version 23.0, SPSS Inc., Chicago, IL) was utilized using relevant statistical constants and relevant statistical tests. The data obtained was tabulated to elucidate descriptive statistics. Receiver operating characteristic (ROC) analysis was used to test the ability of MUAC and AHtR in determining the subjects identified as overweight and/or obesity by BAZ. Here, any subject defined as overweight or obese was coded as 1 and others as 0.The area under the curve (AUC) is a measure of accuracy which is indexed from 0 to 1. The categories used to summarise accuracy in ROC analysis were as follows: 0.9–1 as 'excellent', 0.8–0.9 as 'good', 0.7– 0.8 as 'fair', 0.6–0.7 as 'poor', 0.5–0.6 as 'fail' and <0.5 as worthless test. A value of $p < 0.001$ was considered statistically significant. Sensitivity and specificity were also noted down. The optimal cut-off points were determined by the point of convergence of sensitivity and specificity, by simultaneously maximizing the two. The Youden's Index (J) which is the maximum potential effectiveness of a biomarker was used to determine the optimal sex-specific cut-off levels of MUAC and AHtR to determine overweight and/or obese girls. The likelihood ratios were also calculated. The positive likelihood ratio was calculated by dividing sensitivity by (1-specificity) and the negative likelihood ratio was calculated by dividing (1-senstivity) by specificity.

Results

The subjects were divided into two categories i.e., age-specific child (5-9 years) and adolescent (10-14 years) girls. The groups were formed based on previously published MUAC guidelines (WHO 2009).

Characteristics of the subjects

A total of 1,000 subjects (500 subjects aged 5-9 years and 500 subjects aged 10-14 years) were included in the study. Table 1 depicted the descriptive statistics of the subjects. The mean age of the subjects was 7.42±1.25 years and 12.17±1.38 years for 5-9 years and 10-14 years respectively. The mean MUAC of the subjects was 19.27±2.99 cm and 20.98±2.78 cm for 5-9 years and 10-14 years respectively. The mean AHtR was .159±.019 and .145±.02 for 5-9 years and 10-14 years respectively.

Figure 1 yielded the ROC curve of MUAC and AHtR for the prediction of subjects with higher BAZ. The AUC for MUAC was 0.925 (95%CI: 0.884-0.966; S.E.: .021; $p<0.001$) and 0.919(95%CI: 0.884-0.953; S.E.: .017; $p<0.001$) for age-groups 5-9 and 10-14 years respectively. The AUC for AHtR was 0.928 (95%CI: 0.888-0.967; S.E.: .020; $p<0.001$) and 0.922(95%CI: 0.887-0.958; S.E.: .018; $p<0.001$) for age-groups 5-9 and 10-14 years respectively.

Table 2 bears the best cut-offs extracted on the basis of maximum Youden's index. MUAC≥ 18.75 cm and ≥22.75 cm proved to be the best cut-offs in discriminating subjects with higher BAZ for age-groups of 5-9 and 10-14 years respectively. AHtR≥ 0.169 and ≥0.157 proved to be the best cut-offs in discriminating subjects with higher BAZ for age-groups of 5-9 and 10-14 years respectively.

Discussion

The mean MUAC in the present study was found to be more or less similar to that of other studies (Lu et al. 2014; Rerksuppaphol and Rerksuppaphol 2017). However, the mean is quite higher than the mean MUAC found in the study of Asif et al. (2018). The mean AHtR for both the age-groups in the present study was found to be higher compared to other studies (Table 3).

Further analysis revealed that MUAC≥ 18.75 cm has best sensitivity (97.44%) and moderate specificity (64.66%) and AHtR≥0.169 has good sensitivity (84.62%) and good specificity (88.72%) in discriminating children (of 5-9 years) with higher BAZ. Additionally, MUAC≥22.75 cm with better sensitivity (88.89%) and specificity (83.11%) and AHtR≥ 0.157 with better sensitivity (86.11%) and better specificity (86.49%) proved to be the best cut-offs in discriminating adolescents (of 10-14 years) with higher BAZ. The findings are in consistent with those of other studies (Table 4, Table 5) where it can be found that the stated cut-offs bear excellent AUC values with high sensitivity and specificity.

The present study found that AHtR had greater AUC compared to MUAC in both age groups [(.928 vs .925) for 5-9 years and (.922 vs .919) for 10-14 years] which eventually proved that AHtR had better predictive ability to discriminate the subjects with higher BAZ compared to MUAC. This finding corroborates with that of Rerksuppaphol and Rerksuppaphol (2017).

Likelihood ratios are used for assessing the value of performing a screening/diagnostic test. Likelihood ratios above 10 and below 0.1 are considered to provide strong evidence to rule in or rule out diagnoses respectively in most circumstances (Jaeschke et al., 2002). In other words, the larger the positive likelihood ratio, the more informative are the tools (here, MUAC and AHtR) and the smaller the negative likelihood ratio, the more informative are the tools. In the present study, positive likelihood ratio for MUAC was 2.76 (for 5-9 years) and 5.26 (for 10-14 years) and for AHtR was 7.50 (for 5-9 years) and 6.37 (for 10-14 years). The negative likelihood ratio was 0.04 (for 5-9 years) and 0.13 (for 10-14 years) in case of MUAC while for AHtR, the ratio was 0.173 (for 5-9 years) and 0.160 (for 10-14 years). Moreover, it is also mentioned that findings whose likelihood ratios equal to 1 lack diagnostic value (McGee, 2002). This further proves that MUAC and AHtR have proved to be better tools in predicting children and adolescent girls with higher BAZ.

Conclusion

The present study concluded that both MUAC and AHtR could be proposed as simple and easy tools to discriminate overweight (including obese) children and adolescent girls. The study also revealed that AHtR showed a better predictive ability (in comparison to MUAC) in classifying subjects with higher BAZ. However, more studies are required to confirm this.

Limitations

As with the majority of studies, the design of the present study is subjected to few limitations. Firstly, the study was conducted on a small though appropriate sample size. Secondly, socio-economic and demographic variables were not taken into consideration. Thirdly, pubertal status was not considered at all. Fourthly, the body fat was not measured directly and was rather evaluated in the terms of the BMI classification of the WHO (2007). Lastly, the study was based upon school-aged girls who possibly belong to affluent families which eventually manifests that the findings of the present study would be imprecise to apply for the whole BHCP girls of the given age-groups.

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References

Asif, M., Aslam, M., Altaf, S. (2018). "Mid-upper-arm circumference as a screening measure for identifying children with elevated body mass index: a study for Pakistan". *Korean Journal of Pediatrics* 61(1): 6–11.

Brambilla, P., Rolland-Cachera, M.F., Testolin, C., Briend, A., Salvatoni, A., Testolin, G., Chiumello, G. (2000). "Lean mass of children in various nutritional states. Comparison between dual-energy X-ray absorptiometry and anthropometry". *Annals of the New York Academy of Sciences* 904: 433–436.

Chaput, J. P., Katzmarzyk, P.T., Barnes, J. D., Fogelholm, M., Hu, G., Kuriyan, R., Kurpad, A., Lambert, E. V., Maher, C., Maia, J., Matsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., Tudor-Locke, C., Zhao, P., Tremblay, M.S., ISCOLE Research Group (2017). "Mid-upper arm circumference as a screening tool for identifying children with obesity: a 12-country study". *Pediatric Obesity* 12(6): 439–445.

Choukem, S.P., Kamdeu-Chedeu, J., Leary, S. D., Mboue-Djieka, Y., Nebongo, D. N., Akazong, C., Mapoure, Y. N., Hamilton-Shield, J. P., Gautier, J. F., Mbanya, J. C. (2017). "Overweight and obesity in children aged 3-13 years in urban Cameroon: a cross-sectional study of prevalence and association with socio-economic status". *BMC Obesity* 4: 7.

Craig, E., Bland, R., Ndirangu, J., Reilly, J. J. (2014). "Use of mid-upper arm circumference for determining overweight and overfatness in children and adolescents". *Archives of Disease in Childhood* 99(8): 763–766.

Das Chaudhuri, A.B., Basu, S., Chakraborty, S. (1993). "Twinning rate in the Muslim population of West Bengal". *Acta Geneticae Medicae et Gemellologiae* 42(1): 35–39.

Desalew, A., Mandesh, A., Semahegn, A. (2017). "Childhood overweight, obesity and associated factors among primary school children in dire dawa, eastern Ethiopia; a cross-sectional study". *BMC Obesity* 4:20.

Goto, R., Mascie-Taylor, C. G. N. (2007). "Precision of measurement as a component of human variation". *Journal of Physiological Anthropology* 26(2): 253-256.

Jaeschke, R., Guyatt, G., Lijmer, J. (2002). "Diagnostic tests". In: G. Guyatt, D. Rennie (eds). *Users' guides to the medical literature*, pp. 121-140. Chicago: AMA Press.

Jaiswal, M., Bansal, R., Agarwal, A. (2017). "Role of Mid-Upper Arm Circumference for Determining Overweight and Obesity in Children and Adolescents". *Journal of Clinical and Diagnostic Research* 11(8): SC05-SC08.

Jayawardene, W., Dickinson, S., Lohrmann, D., Agley, J. (2018). "Arm Circumference-to-Height Ratio as a Situational Alternative to BMI Percentile in Assessing Obesity and Cardiometabolic Risk in Adolescents". *Journal of Obesity* 2018: 7456461.

Kulathinal, S., Freese, R., Korkalo, L., Ismael, C., Mutanen, M. (2016). "Mid-upper arm circumference is associated with biochemically determined nutritional status indicators among adolescent girls in Central Mozambique". *Nutrition Research* 36(8): 835-844.

Lu, Q., Wang, R., Lou, D. H., Ma, C. M., Liu, X. L., Yin, F. Z. (2014). "Mid-upper-arm circumference and arm-to-height ratio in evaluation of overweight and obesity in Han children". P*ediatrics and Neonatology* 55(1): 14-19.

Ma, C.M., Li, Y., Gao, G. Q., Yin, F. Z., Wang, R., Liu, X. L., Lu, Q. (2015). "Mid-upper arm circumference as a screening measure for identifying children with hypertension". *Blood Press Monitoring* 20(4): 189-193.

McGee, S. (2002). "Simplifying Likelihood Ratios". *Journal of General Internal Medicine* 17(8): 647-650.

Meharda, B., Sharma, S.K., Singhal, G., Kumar, D. (2017). "Overweight and obesity: a rising problem in India". *International Journal of Community Medicine and Public Health* 4(12): 4548-4552

Mramba, L., Ngari, M., Mwangome, M., Muchai, L., Bauni, E., Walker, A.S., Gibb, D. M., Fegan, G., Berkley, J. A. (2017). "A growth reference for mid upper arm circumference for age among school age children and adolescents, and validation for mortality: growth curve construction and longitudinal cohort study". *BMJ* 358: j3423.

Oyhenart, E.E., Castro, L.E., Garraza, M., Cesani, M.F., Torres, M.F., Quintero, F.A., Dahinten, S.L., Alfaro, E.L., Bejarano, I.F., Carrillo, R.Á., Dip, N.B., Lomaglio, D., Marrodán, M.D., Menecier, N., Navazo, B., Román, E.M., Zonta, M.L., Dipierri, J. E. (2019). "Comparative study of mid-upper arm circumference, arm muscle area and arm fat area percentiles in Argentinean and US children aged 4-14 years". *Nutricion Hospitalaria* 36(3): 552-562.

Ozturk, A., Budak, N., Cicek, B., Mazicioglu, M. M., Bayram, F., Kurtoglu, S. (2009). "Cross-sectional reference values for mid-upper arm circumference, triceps skinfold thickness and arm fat area of Turkish children and adolescents". *International Journal of Food Sciences and Nutrition* 60(4): 267-281.

Pandita, A., Sharma, D., Pandita, D., Pawar, S., Tariq, M., Kaul, A. (2016). "Childhood obesity: prevention is better than cure". *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy* 9: 83-89.

Pangani, I.,N., Kiplamai, F.,K., Kamau, J.,W., Onywera, V. O. (2016). "Prevalence of Overweight and Obesity among Primary School Children Aged 8-13 Years in Dar es Salaam City, Tanzania". *Advances in Preventive Medicine* 2016: 1345017.

Perini, T.A., de Oliveira, G.L., Ornellas, J.S., de Oliveira, F. P. (2005). "Technical error of measurement in anthropometry". *Revista Brasileira de Medicina do Esporte* 11: 86-90.

Reilly, J. J., Kelly, J. (2011). "Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review". *International Journal of Obesity* 35(7): 891-898.

Rerksuppaphol, S., Rerksuppaphol, L. (2017). "Mid-Upper-Arm Circumference and Arm-to-Height Ratio to Identify Obesity in School-Age Children". *Clinical Medicine & Research* 15(3-4): 53-58.

Sahoo, K., Sahoo, B., Choudhury, A. K., Sofi, N. Y., Kumar, R., Bhadoria, A. S. (2015). "Childhood obesity: causes and consequences". *Journal of Family Medicine and Primary Care* 4(2): 187-192.

Singh, I.P., Bhasin, M.K. (1989). Anthropometry. Delhi: Kamla-Raj Enterprise.

Talma, H., van Dommelen, P., Schweizer, J. J., Bakker, B., Kist-van Holthe, J. E., Chinapaw, J. M. M., Hirasing, R. A. (2019). "Is mid-upper arm circumference in Dutch children useful in identifying obesity?" *Archives of Disease in Childhood* 104(2): 159-165.

Touitou, Y., Portaluppi, F., Smolensky, M. H., Rensing, L. (2004). "Ethical principles and standards for the conduct of human and animal biological rhythm research". *Chronobiology International* 21(1): 161-170.

Tran, B. X., Dang, K. A., Le, H. T., Ha, G. H., Nguyen, L. H., Nguyen, T. H., Tran, T. H., Latkin, C. A., Ho, C. S. H., Ho, R. C. M. (2019). "Global Evolution of Obesity Research in Children and Youths: Setting Priorities for Interventions and Policies". *Obesity Facts* 12(2): 137-149.

Ulijaszek, S. J., Kerr, D. A. (1999). "Anthropometric measurement error and the assessment of nutritional status". *The British Journal of Nutrition* 82(3): 165–177.

WHO. (2007). "WHO Child Growth Standards". <http://www.who.int/childgrowth/en/> (Accessed July 12 2020).

WHO. (2009). "AnthroPlus for Personal Computers Manual: Software for Assessing Growth of the World's Children and Adolescents". Geneva, Switzerland: World Health Organization.

WHO. (2009). "Guidelines for an intergrated approach to the nutritional care of HIV-infected children (6 months-14 years)".

Xu, S., Xue, Y. (2016). "Pediatric obesity: Causes, symptoms, prevention and treatment". *Experimental and therapeutic medicine* 11(1): 15–20.

Tables and Pictures

Table 1. Descriptive statistics of the subjects.

Age-groups (years)	No.	Age in years Mean (SD)	BAZ Mean (SD)	MUAC in cm Mean (SD)	AHtR Mean (SD)
5-9	500	7.42(1.25)	-.56(1.89)	19.27(2.99)	.159(.019)
10-14	500	12.17(1.38)	-.35(1.37)	20.98(2.78)	.145(.020)

Table 2. Cut-off point, sensitivity, specificity and likelihood ratios of MUAC and AHtR for detecting overweight (including obese) subjects.

Age-groups	Cut-offs	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio
5-9 years	MUAC ≥ 18.75cm	97.44	64.66	2.76	0.04
	AHtR ≥0.169	84.62	88.72	7.50	0.17
10-14 years	MUAC ≥ 22.75cm	88.89	83.11	5.26	0.13
	AHtR ≥0.157	86.11	86.49	6.37	0.16

Table 3. Comparison of mean MUAC and AHtR of children and adolescent girls from different studies.

Study	Location	Sample size	Age-groups (yrs)	Mean±SD	
				MUAC (cm)	**AHtR**
Lu et al., 2014	Qinhuangdao, China	1372	7-12	20.2±3.2	0.143±0.019
Rerksuppaphol & Rerksuppaphol, 2017	Thailand	1788	6.00-12.99	19.3±3.7	0.143±0.022
Asif et al., 2018	Pakistan	3900	5-14	17.49±2.52	-
Present study	West Bengal, India	500	5-9	19.27±2.99	0.159±0.019
		500	10-14	20.98±2.78	0.145±0.020

Table 4. Comparison of MUAC cut-offs with sensitivity and specificity from different studies.

Study	Location	Age-groups (years)	Sample size	Cut-offs (cm)	Sensitivity (%)	Specificity (%)	AUCs
Craig et al., 2014	Rural South Africa	5-9	235	18.3/18.85	97.1/94.1	79.1/88.1	0.96
		10-14	269	22.45/22.8	92.9/88.1	78.0/81.1	0.94
Lu et al., 2014	Qinhuangdao, China	7-12	1372	18.9-23.4	83.6-94.5	81.7-94.0	0.934-0.975
Rerksuppaphol & Rerksuppaphol, 2017	Thailand	6.0-12.99	1788	18.0-23.2	73.5-82.5	87.7-95.6	0.905–0.931
Asif et al., 2018	Pakistan	5-14	3900	16.38-20.57	57-90	55-94	0.733-0.912
Present Study	West Bengal, India	5-9	500	18.75	97.44	64.66	0.925
		10-14	500	22.75	88.89	83.11	0.919

Table 5. Comparison of AHtR cut-offs with sensitivity and specificity from different studies

Study	Location	Age-groups	Sample size	Cut-offs	Sensitivity (%)	Specificity (%)	AUCs
Lu et al., 2014	Qinhuangdao, China	7-12	1372	0.15	85.4	87.8	0.935
Rerksuppaphol & Rerksuppaphol, 2017	Thailand	6.0-12.99	1788	0.145	87.6	86.6	0.975
Present Study	West Bengal, India	5-9	500	0.169	84.62	88.72	0.928
		10-14	500	0.157	86.11	86.49	0.922

Figure 1. ROC curve analysis showing ability of MUAC and AHtR to predict overweight (including obese) subjects