ORIGINAL ARTICLE

Diagnostic Accuracy of Waist Circumference and Waist-to-Height Ratio for Moderate and Severe Acute Malnutrition in Under-5 Children

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ABSTRACT

Objective: To determine the most appropriate cut-off values of Waist Circumference (WC) and Waist-to-Height Ratio (WHtR) for diagnosing moderate acute malnutrition (MAM) and severe acute malnutrition (SAM) in under-five children.

Methods: This cross-sectional diagnostic accuracy study was conducted between January 2021 and August 2022 in the Department of Pediatrics of a tertiary hospital in Delhi. Children aged 6 months to 5 years attending the outpatient or emergency services were included in the study. Detailed clinical evaluation and anthropometry including measurement of WC were done at enrollment. Body mass index (BMI) and WHtR were calculated. Malnutrition was classified as per the WHO criteria. Receiver operating characteristic curves (sensitivity, specificity) for WC and WHtR (absolute values) were drawn against the standard test of WHO definitions for MAM and SAM to determine the most appropriate cut-offs for diagnosing MAM and SAM.

Results: 1500 children with a median (IQR) age of 29 (14, 43) months were enrolled; 21% children had MAM and 11% had SAM as per the WHO criteria. WC < 44.5 cm (sensitivity 74.1%, specificity 71.1%) and WHtR < 0.565 (sensitivity 75.6%, specificity 33.7%) were the best cut-offs to identify MAM, whereas WC < 42.3 cm (sensitivity 67.5%, specificity 81.3%) and WHtR < 0.563 (sensitivity 81.3%, specificity 33.4%) were the best cut-offs to diagnose SAM.

Conclusion: Waist circumference (< 44.5 cm for MAM; < 42.3 cm for SAM) had a reasonably good sensitivity and specificity for diagnosing MAM and SAM, but the same was not true for WHtR.

Keywords: *Anthropometry, Child, Nutrition, Obesity, Screening, Undernutrition, Wasting*

INTRODUCTION

India is currently undergoing major epidemiological, nutritional and demographic transition. Obesity and overweight in children and adolescents are on the rise across all socioeconomic groups, while undernutrition still prevails as the major concern. India as a developing country is facing a new and unique problem of double burden of malnutrition (DBM), which is coexistence of undernutrition along with overweight and obesity [1]. For mass level screening of populations where undernutrition and obesity both are prevalent, it may be useful to have a single parameter that can detect both extents of malnutrition.

Waist circumference (WC) is a measure of distribution of body fat, and has been shown to be strongly associated with obesity-related morbidity and mortality. Waist circumference to height ratio, or waist-to-height ratio (WHtR) is another parameter for central fat distribution, and could be applicable universally regardless of race, age and perhaps even gender [2,3]. Though, WC and WHtR are surrogate markers of body composition, and have been used in overweight and obesity, these parameters have not been evaluated for diagnosing undernutrition; and their age-independence, and cut-offs for the diagnosis of moderate and severe forms of malnutrition have not been evaluated. Therefore, this study was conducted with the aim of evaluating the role of WC and WHtR in under-five children for the diagnosis of moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). We also aimed to compare their diagnostic performance in under-five children with and without stunting.

METHODS

This cross-sectional diagnostic accuracy study was conducted in the department of pediatrics, of Guru Teg Bahadur hospital attached to University College of Medical Sciences, Delhi, between January 2021 and August 2022. A written informed consent was obtained from the caregivers of all participants. An approval was obtained from the Institutional Ethics Committee, prior to commencing the study.

Children aged 6 months to 5 years attending the outpatient or emergency services for any complaint or routine immunization or well-baby visits were included. Children with known chronic systemic illnesses (*e.g,* tuberculosis, liver disease, cancer, cardiac or renal disease), those with clinical features suggestive of dehydration or congestive heart failure, critically ill children (*e.g*, those on ventilation, oxygen therapy or having very severe illness), and children with trunk or limb deformities (*e.g.*, kyphosis, scoliosis, genu valgum, skeletal dysplasias) were excluded from the study.

At enrolment, children were screened for eligibility after verifying their birth records or by parent recall to the closest date near birth. Demographic data were collected and recorded in a pre-designed proforma and socioeconomic status was categorized using the modified Kuppuswamy scale [4]. Weight, length or height, head circumference, mid upper-arm circumference (MUAC) and WC were measured by a single observer using standard methods [5]. Weight was measured using the electronic weighing scale after calibrating for zero error and using tare function, height was taken with a stadiometer and length was measured using an infantometer. A non-stretchable measuring tape (SECA, Germany) was used to measure the WC making the child stand upright, and applying the measuring tape horizontally just above the upper lateral border of the right ileum, ensuring that the tape is parallel to the ground. For children < 2 years, WC was measured at the same site in the standing position if the child was able to stand with support (upper torso held firmly), and in the recumbent position if the child was unable to stand even with support of torso. Measurement was made at the end of a normal expiration to the nearest 0.1 cm [6]. WHtR was calculated as Waist (cm)/Height (cm), and BMI was calculated as body weight (kg)/height^2 (meters). Weight-for-length/height z-score (WHZ), weight-for-age z-score (WAZ), height-for-age z-score (HAZ), BMI-for-age z-score (BMIZ) and mid upper arm z-score (MUACZ) were calculated using the WHO Anthro software [7].

Stunting, underweight, and wasting were graded and defined as per the WHO growth standards [8]. SAM and MAM were classified as per the WHO criteria [9,10]. Children with SAM and other comorbidities were admitted and treatment was provided as per the WHO and IAP protocol [9,11]. Children with uncomplicated SAM and MAM were counseled for appropriate calorie, protein and micronutrient intake as per their requirements, and were followed-up on outpatient basis.

A previous study by Khadilkar et al [12], reported AUC of 0.9 for boys and 0.8 for girls for performance of WC for detecting risk factors for metabolic syndrome whereas Hubert et al [13] reported AUC of 0.93-0.86 for WC and 0.9-0.95 for WHtR for detecting obesity in children. Assuming an AUC of 0.85 for both WC and WHtR for diagnosis of MAM as per WHO criteria, a sample size resulting in 151 children with MAM was calculated to be sufficient with 0.05 marginal error (d) and 95% confidence level [14]. Based on a previous study from our setting [15] where the prevalence of MAM was reported as 20%, a sample size of 750 children was calculated to enrol 151 children with MAM. We thus enrolled 1500 children with the aim to include sufficient number of boys and girls with MAM.

Statistical analysis: Data were analyzed using SPSS Version 21.0. Receiver operating characteristic (ROC) curves were drawn for WC and WHtR against diagnosis of MAM and SAM based on WHO criteria. For diagnosis of MAM and SAM, the most appropriate cut-offs for WC and WHtR were determined using summary measure of Youden index (sensitivity+specificity-1) for best performance against WHO criteria. WC and WHtR were also compared in stunted and non-stunted under-five children by comparing their means by unpaired student-t test. Diagnostic performance for MAM in stunted and non-stunted children was explored separately from ROC curves. $P < 0.05$ was considered statistically significant.

RESULTS

A total of 1500 children were enrolled, with a median (IQR) age of 29 (14, 43) months, 18% ($n = 265$) were infants. The mean (SD) WAZ, HAZ, WHZ, BMIZ scores and MUAC of enrolled children were -1.56 (1.28), -1.25 (1.61), -1.21 (1.36), -1.12 (1.38) and 13.71 (1.40), respectively. 31%, 26% and 36% of all children were stunted, wasted and underweight, respectively. Overall, 21% children had MAM and 11% had SAM as per WHO criteria. The gender-wise demographic profile of all children is depicted in **Table I.**

The mean (SD) WC of the enrolled children was 45.2 (4.2) cm and mean (SD) WHtR was 0.539 (0.059). The 3rd percentile of WC in our study was 37.0 cm whereas the 97th percentile was 53.0 cm, and for WHtR was 0.449 whereas the 97th percentile was 0.659 respectively see (**Table II).** WC had a significant positive correlation with MUAC ($r = 0.679$, $P < 0.001$) whereas WHtR had a significant negative correlation with MUAC ($r = -0.083$, $P = 0.001$).

The area under the curve [AUC (95% CI)] for WC for diagnosing MAM was 0.795 (0.771, 0.820); $P < 0.001$ (**Fig. 1a**); and for diagnosis of SAM was 0.814 (0.778, 0.850), $P < 0.001$ (**Fig. 1b**). Regarding the diagnostic performance for MAM for various WC cut-offs on ROC curve, Youden index was maximum (0.452) for WC cut-off of 44.5 cm with a sensitivity of 74.1% and specificity of 71.1%. whereas for SAM, Youden index was maximum (0.488) for WC cut-off of 42.3 cm with a sensitivity of 67.5% and specificity of 81.3%.

The AUC (95% CI) for WHtR for diagnosing MAM was 0.568 (0.537, 0.599); $P < 0.001$ (**Fig. 1c**) and for SAM was 0.595 (0.550, 0.639); $P < 0.001$ (**Fig. 1d).** Regarding the diagnostic performance for MAM and SAM for various WHtR cut-offs on ROC curve, Youden index was ≤ 0.15 for all cut-off values. Out of all cut-offs, the diagnostic performance was best (Youden index 0.093) for WHtR of 0.565 (sensitivity 75.6%, specificity 33.7%) for MAM, whereas for SAM, Youden index was found to be maximum (0.147) for WHtR of 0.563 (sensitivity 81.3%, specificity 33.4%).

On comparing the WC and WHtR in children with and without stunting, the mean (SD) WC was significantly ($P < 0.001$) less for stunted children, whereas the mean (SD) WHtR was significantly ($P < 0.001$) higher for those with stunting. ROC curves depicting the performance of WC and WHtR for diagnosis of MAM in children with and without stunting is shown in **Web Fig. 1.**

The cut-off values for all the parameters for diagnosis of MAM and SAM with respective AUC obtained for different parameters are summarized in **Table III.** Using the same WC cut-off (< 44.5 cm) as determined from all children, the sensitivity was higher with some compromise in specificity in children with stunting (sensitivity 82.2%, specificity 65.4%) whereas in children without stunting, there was a decrease in sensitivity with slightly higher specificity (sensitivity 68.4%, specificity 73.2%).

DISCUSSION

In this diagnostic accuracy study, enrolling 1500 children, WC cut-off < 44.5 cm (sensitivity 74.1%, specificity 71.1%) and WHtR cut-off < 0.565 (sensitivity 75.6%, specificity 33.7%) were obtained to diagnose MAM, whereas WC < 42.3 cm (sensitivity 67.5%, specificity 81.3%) and WHtR < 0.563 (sensitivity 81.3%, specificity 33.4%) were obtained to diagnose SAM. WC had a reasonably good sensitivity and specificity for the diagnosis of MAM and SAM as compared to WHtR, which seemed to be a poor indicator to identify the nutritional status of children with cut-off values almost similar for SAM and MAM. WC cut-off < 44.5 cm served equally well for the diagnosis of MAM in stunted and non-stunted children.

In this study the mean (SD) WAZ, HAZ, WHZ and BMIZ of enrolled children were -1.56 (1.28), -1.25 (1.61), -1.21 (1.36) and -1.12 (1.38), respectively. Compared to the nationwide survey done in India (CNNS 2019) [16] our group of children had a lower proportion of wasting but higher proportion of stunting which could be related to the differences in the profile of the population visiting our hospital. As per the CNNS survey, the prevalence of stunting in Delhi was 29% which is similar to that in our study. The centile values derived in our study should not be used as reference for normal population because of a large proportion of children with undernutrition were observed in our hospital-based study, although the trends of WC and WHtR with age observed by us is comparable to other reference studies [12,17].

In our study, WC had a reasonably good sensitivity and specificity for the diagnosis of MAM and SAM, but the same was not true for WHtR. Performance of WHtR was poor and the cut-off values for SAM and MAM were almost similar. We identified cut-off of WC to diagnose MAM in stunted children and in children without stunting. This showed that using a uniform cut-off of 44.5 cm in the mixed population should suffice to screen for MAM in both stunted and non-stunted under-five children. A cross-sectional cluster study by Lloyd and Lederman included 609 children aged 3-5 years from Ethiopia, India, and Brazil and found that WC is a good marker to identify MAM [18]. It also reported that its performance was comparable to weight-for-height, but the WC cut-off was much higher which may be due to the use of National Center for Health Statistics (NCHS) standards in their study compared to the WHO reference standards used in our study. NCHS references are derived from formula-fed children who have higher body weight and fat mass while the WHO growth references have been obtained from optimally fed children who are comparatively leaner.

Moreover, they used weight-for-age to diagnose MAM without accounting for the contribution of height to the body weight. This is also reflected in the much higher MUAC cut-off for MAM given by this study (< 15.5 cm) as compared to the WHO cut-off (< 12.5 cm).

WHtR was not found suited for the assessment of nutritional status in under-five children. We observed that although WC increased with age, WHtR decreased with age in both genders which was similar to the findings of Roswall et al [19] in Swedish under-five children. We also observed that WHtR < 0.5 which is used to identify metabolic risk in adolescents and school children, does not apply to pre-school children. Thus, there is a need to establish age-specific references for WHtR in under-five children. We also observed that WhtR < 0.5 cut-off is in appropriate to diagnose overnutrition as the mean values varied from 0.480 to 0.613 in different age and sex groups.

The main strength of our study is the use of comprehensive screening markers for identifying both the extremes of malnutrition. All anthropometric measurements were taken by a single observer using a standardized methodology to ensure precision. We enrolled an adequate sample of both genders. We also had a sufficient number of children with MAM (20%) and SAM (10%), which conformed to the sample size estimates. The fact that ours was a hospital-based study and the sample size within each age subgroup may not have been sufficient to firmly comment on the statistical validity of the results to each age subgroup are few of the limitations of this study.

We conclude that WC has a good diagnostic performance for screening for MAM and SAM, with the cut-offs of 44.5 cm and 42.3 for MAM and SAM, respectively. WHtR cannot distinguish MAM and SAM reliably. As, these cut-offs are obtained from children living in an urban area and belonging to lower- and middle-income socioeconomic strata, their diagnostic performance in higher income and rural populations needs to be further explored. We recommend community-based studies with sufficient sample size across various pediatric age subgroups to assess the diagnostic performance of waist circumference to screen for both forms of malnutrition, under and over-nutrition, in transitioning populations with dual burden of malnutrition.

Ethics clearance: Institutional Ethics Committee – Human Research (IEC–HR) of University College of Medical Sciences, Delhi No. IECHR/2020/PG/46/75, dated Dec 21, 2020.

Contributors: VS: Data collection, drafting the manuscript; SK: Data analysis and interpretation, critical inputs, revision of the initial draft; DS: Conceptualized and designed the study, analyzed and interpreted the data, revised the manuscript; PG: Conceptualized and designed the study, provided critical inputs. All authors approved the final manuscript and are willing to be accountable for all aspects of the study.

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WHAT THIS STUDY ADDS?

- Waist circumference has a reasonably good diagnostic performance for the diagnosis of MAM and SAM
- Waist circumference < 44.5 cm (sensitivity 74.1%, specificity 71.1%) and < 42.3 cm (sensitivity 67.5%, specificity 81.3%) can diagnose MAM and SAM, respectively.
- Waist-to-height ratio cannot reliably diagnose MAM and SAM.

REFERENCES

1. Ranjani H, Mehreen TS, Pradeepa R, et al. Epidemiology of childhood overweight and obesity in India: A systematic review. Ind J Med Res.2016;143:160-74.
2. Jensen NS, Camargo TF, Bergamaschi DP. Comparison of methods to measure body fat in 7 to10 year old children: A systematic review. Public Health. 2016;133:3-13.
3. Sardinha LB, Santos DA, Silva AM, Grøntved A, Andersen LB, Ekelund U. A comparison between BMI, waist circumference, and waist-to-height ratio for identifying cardio-metabolic risk in children and adolescents. PLoS One. 2016;11:e0149351.
4. Sharma R. Revised Kuppuswamy's Socioeconomic Status Scale: Explained and updated. Indian Pediatr. 2017;54:867-70.
5. United Nations. How to weigh and measure children, 1986. Accessed on Oct 22, 2020. Available from: *https://unstats.un.org/unsd/publication/unint/dp_un_int_81_041_6E.pdf*
6. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). Anthropometry Procedures Manual. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2004. Accessed June 18, 2022. Available from: *http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/BM.pdf*
7. WHO Anthro for personal Computers, version 3.2.2, 2011: Software for Assessing Growth and Development of the World's Children. Geneva: WHO, 2010. Accessed on June 20, 2022. Available from: *https://www.who.int/childgrowth/software/en/*
8. World Health Organization, WHO Multicentre Growth Reference Study Group. WHO Child Growth Standards: Length/height-for-age, Weight-for-Age, Weight-for- length, Weight-for-height and Body mass index-for-age: Methods and Development, 2006. Accessed on February 8, 2022. Available from: *https://www.who.int/childgrowth/standards/technical_report/en/*
9. WHO/UNICEF. A Joint Statement by the World Health Organization and the United Nations Children's Fund. WHO child Growth Standards and the Identification of Severe Acute Malnutrition in Infants and Children 2009. Accessed on February 6, 2022.Available from: http://apps.who.int/iris/bitstream/10665/44129/1/ 9789241598163_eng.pdf
10. World Health Organization, e-library of Evidence for Nutrition Actions (e LENA), 2019. Accessed on February 8, 2022. Available from: *https://www.who.int/elena/titles/food_children_mam/en/*
11. Bhatnagar S, Lodha R, Choudhury P, et al. Indian Academy of Pediatrics, IAP Guidelines 2006 on Hospital Based Management of Severely Malnourished Children (Adapted from the WHO Guidelines), 2006. Indian Pediatr. 2007;44:443-461.
12. Khadilkar A, Ekbote V, Chiplonkar S, et al. Waist circumference percentiles in 2-18 year old Indian children. J Pediatr. 2014;164:1358-62.

13. Hubert H, Guinhouya CB, Allard L, Durocher A. Comparison of the diagnostic quality of body mass index, waist circumference and waist-to-height ratio in screening skinfold-determined obesity among children. J Sci Med Sport. 2009;12:449-51.
14. Hajian-Tilaki K. Sample size estimation in diagnostic test studies of biomedical informatics. J Biomed Inform. 2014;48:193-204.
15. Sethi M. Validation of mid upper arm circumference cut offs to predict severe wasting. Thesis submitted to the Faculty of Medical Sciences, University of Delhi for the degree of Doctor of Medicine (Pediatrics), April 2013.
16. Comprehensive National Nutrition Survey (CNNS) National Report 2019. Accessed on June 6, 2022. Available from: *https://nhm.gov.in/WriteReadData/l892s/1405796031571201348.pdf*
17. Inokuchi M, Matsuo N, Takayama J I, Hasegawa T. Population-based waist circumference reference values in Japanese children (0–6 years): Comparisons with Dutch, Swedish and Turkish preschool children. J Pediatr Endocrinol Metab.2021;34:349-56.
18. Lloyd ME, Lederman SA. Anthropometry and moderate malnutrition in preschool children. Indian J Pediatr. 2002;69:771-4.
19. Roswall J, Bergman S, Almqvist-Tangen G, et al. Population-based waist circumference and waist-to-height ratio reference values in preschool children. Acta Paediatr. 2009;98:1632-6.

Table I Gender-wise Demographic Profile of Enrolled Population (*n* = 1500)

	Boys (*n* = 783)	Girls (*n* = 717)	Total (*n* = 1500)
6 months – 1 year	132 (8.8)	133 (8.9)	265 (17.7)
1 - 2 years	183 (12.2)	179 (11.9)	362 (24.1)
2 – 3 years	167 (11.1)	150 (10)	317 (21.1)
3 - 4 years	141 (9.4)	128 (8.5)	269 (17.9)
4 - 5 years	160 (10.6)	127 (8.5)	287 (19.1)
Stunting[a]	253 (32.3)	216 (30.1)	469 (31.3)
Wasting[b]	200 (25.5)	190 (26.5)	390 (26)
Underweight[c]	277 (35.4)	266 (37.1)	543 (36.2)
MAM	151 (19.3)	168 (23.4)	319 (21.3)
SAM	82 (10.5)	78 (10.9)	160 (10.7)

Values expressed as n (%)
MAM Moderate acute malnutrition, SAM Severe acute malnutrition
[a]includes severe stunting, [b]includes severe wasting, [c]includes severe underweight

Table II Age-wise Distribution and Percentile Distribution of Waist Circumference and Waist-to-Height ratio in the Enrolled Children (*n* = 1500)

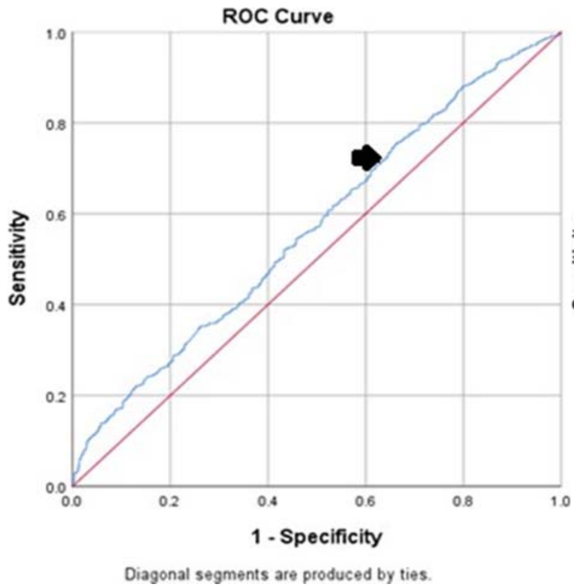
	Waist circumference (cm)		*Waist-to-Height Ratio*	
	Boys	*Girls*	*Boys*	*Girls*
6-60 months[a] (*n* = 1500; 783 boys, 717 girls)	45.6 (4.1)	44.6 (4.2)	0.539 (0.06)	0.539 (0.05)
6-11 months[a] (*n* = 265; 132 boys, 133 girls)	42.3 (3.4)	40.7 (3.5)	0.613 (0.04)	0.598 (0.05)
12-23 months[a] (*n* = 362; 183 boys, 179 girls)	43.7 (3.6)	43.1 (3.4)	0.562 (0.04)	0.561 (0.04)
24-35 months[a] (*n* = 317; 167 boys, 150 girls)	46.2 (3.2)	45.5 (3.2)	0.535 (0.03)	0.531 (0.03)
36-47 months[a] (*n* = 269; 141 boys, 128 girls)	47.5 (3.0)	47.1 (3.5)	0.506 (0.04)	0.514 (0.04)
> 47 months[a] (*n* = 287; 160 boys, 127 girls)	48.7 (3.5)	47.9 (3.1)	0.484 (0.03)	0.48 (0.03)
Median (IQR)	45.1 (42.5, 48.0)		0.53 (0.49, 0.57)	
3rd percentile	37.0		0.449	
15th percentile	41.0		0.478	
50th percentile	45.1		0.534	
85th percentile	49.3		0.600	
97th percentile	53.0		0.659	

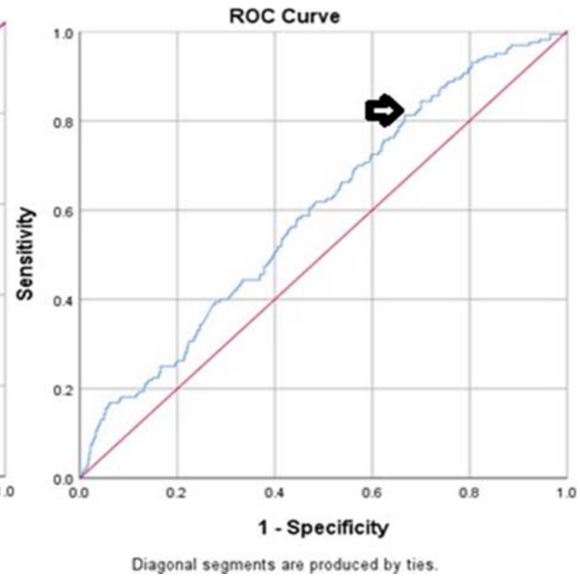
Values presented as [a]mean (SD)
WC Waist circumference, WHtR Waist-to-height ratio

Table III Cut-off Values and Area Under the Curve (AUC) for Waist Circumference and Waist-to-height ratio for Diagnosis of MAM and SAM

Parameter	*Moderate Acute Malnutrition*		*Severe Acute Malnutrition*	
	Cut-off (cm) (Sensitivity, Specificity)	*AUC (95% CI)*	*Cut-off (Sensitivity, Specificity)*	*AUC (95% CI)*
Waist circumference				
All (*n* = 1500)	44.5 (74.1%, 71.1%)	0.79 (0.77, 0.82)	42.3 (67.5%, 81.3%)	0.81 (0.78, 0.85)
Stunting (*n* = 469)	43.0 (68.5%, 82.0%)	0.81 (0.77, 0.85)		
No stunting (*n* = 1031)	44.0 (66.7%, 76.6%)	0.77 (0.74, 0.80)		
Waist-to-height ratio				
All (*n* = 1500)	0.56 (75.6%, 33.7%)	0.57 (0.54, 0.60)	0.56 (81.3%, 33.4%)	0.59 (0.55, 0.63)
Stunting (*n* = 469)	0.50 (30.5%, 85.3%)	0.58[a] (0.53, 0.63)		
No stunting (*n* = 1031)	0.56 (77.0%, 34.7%)	0.57 (0.53, 0.61)		

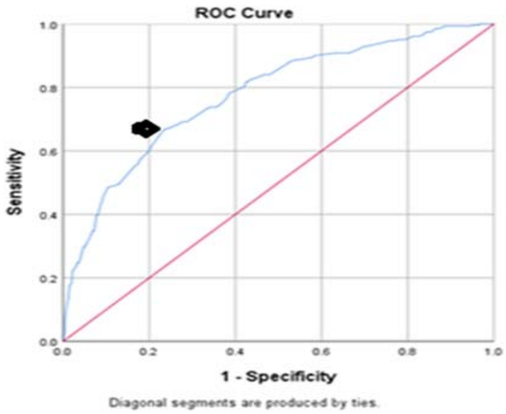
WC Waist circumference, WHtR Waist-to-height ratio
[a]P = 0.002, P < 0.001 for rest of the values

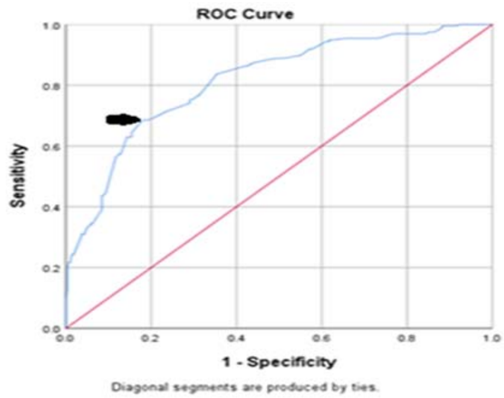




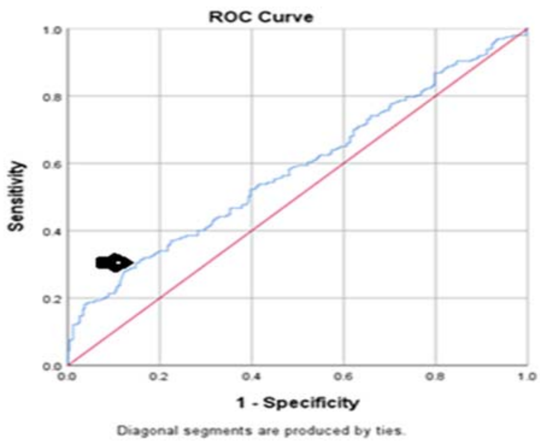
1a **1b**

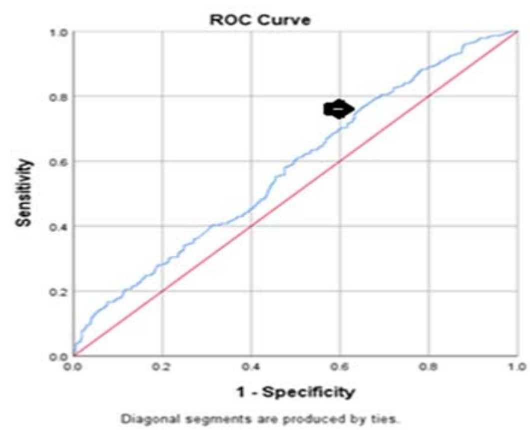
Fig 1. ROC curve for performance of waist circumference for the diagnosis of MAM (1a) and SAM (1b) and waist-to-height ratio for the diagnosis of MAM (1c) and SAM (1d). Arrows indicate best cut-off value.





1a **1b**





1c **1d**

Web Fig.1. ROC curves for performance of waist circumference for diagnosis of MAM in children with stunting (1a) and children without stunting (1b); and waist-to-height ratio for diagnosis of MAM in children with stunting (1c) and children without stunting (1d). Arrows indicate best cut-off value.