

# Prediction of growth and nutritional status using circumference measurements among preschool children in Jalpaiguri West Bengal India

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## Research Article

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## Abstract

**Introduction:** Undernutrition remains a major public health challenge among preschool children in low- and middle-income countries. Conventional anthropometric measures are widely used to assess nutritional status due to simple, non-invasive, and low-cost alternatives. However, population-specific cut-off values, particularly for chest circumference, are largely unavailable among Indian preschool children.

**Aim:** The present cross-sectional study assessed the utility of head circumference (HC), chest circumference (CC), and mid-upper arm circumference (MUAC) for predicting undernutrition and derived optimal cut-off values among 1,240 preschool children (625 boys and 615 girls) aged 2-5 years from ICDS centres in Jalpaiguri district, West Bengal, India. Anthropometric measurements were recorded following standard protocols, and nutritional status was evaluated using WHO 2006 Z-score criteria.

**Results:** Binary logistic regression and receiver operating characteristic analyses were employed to determine predictive accuracy and optimal cut-offs using the Youden Index. The prevalence of undernutrition ranged between 13.79% for wasting, 24.43% for stunting, 25.00% for underweight, 25.32% for low HC for age, and 25.40% for low MUAC for age, with higher deficiency observed among girls. All circumference measures increased significantly with age and exhibited sexual dimorphism. The CC emerged as the strongest predictor of underweight and stunting, while MUAC demonstrated superior accuracy in identifying wasting. Optimal cut-off values ranged from 45.5-47.9 cm for HC, 48.0-49.3 cm for CC, and 13.4-14.0 cm for MUAC.

**Conclusion:** These findings highlight the effectiveness of circumference-based anthropometric measures as reliable screening tools for undernutrition. HC, CC, and MUAC can serve as practical screening measures for childhood undernutrition. CC may complement MUAC, particularly for identifying underweight and stunting.

## Introduction

Undernutrition is the major cause of child morbidity and mortality in lower-middle-income countries as well as India [1]. According to UNICEF [2], the under-five mortality rate was 25 in 1000 live births in West Bengal and 34 in 1000 live births in India. In Indian preschool children, circumference-based nutritional assessment was utilized in the last few decades to measure the nutritional condition during childhood. Besides the conversational anthropometric measures like underweight (WAZ), stunting (HAZ), and wasting (WHZ), recently low head circumference (HCZ) and low mid-upper arm circumference (MUACZ) have been proposed as proxy measures of child undernutrition.

Head circumference and mid-upper arm circumference are mostly utilized in nutritional surveys and screening programmes to diagnose malnutrition [3]. Head circumference measures cognitive or brain development during childhood [3]. Mid-upper arm circumference is mostly utilized for screening of acute malnutrition (wasting). Chest circumference measures also assess nutrition but are rarely used due to a lack of standardized cutoffs among preschool children.

In population-based research, the most popularly used methods were low weight for age, low height for age, and low height for weight. Several studies reported the head circumference-based nutritional status [4–9] and mid-upper arm circumference-based nutritional status [10–14] in Indian preschool children. The present study assesses underweight, stunting, and wasting by using age- and sex-specific calculations derived from height and weight. The present study assesses low head circumference for age and low mid-upper arm circumference for age by the standard cutoff values developed by WHO. Given their simplicity, ease of measurement, and low cost in nature, HC and MUAC could be effectively utilized as a screening anthropometric indicator in large-scale population studies, in contrast to traditional anthropometric methods. We cannot assess undernutrition from chest circumference due to lack of cutoff values. The HC and MUAC are considered better surrogate anthropometric measures of undernutrition.

Several researchers have reported positive associations between conventional anthropometric measures such as WAZ, HAZ, and WHZ with circumference measures [3, 15–18]. Previous research has reported that MUAC has the potential accuracy for the prediction of child undernutrition (wasting) [19, 20]. Previous studies done to establish the relationship of circumference measures like MUAC with acute malnutrition [21–24].

Population-specific cut-off studies are largely lacking among Indian preschool children. Therefore, the identification of alternative anthropometric measurements (e.g., HC, CC, and MUAC) for assessing undernutrition in early childhood is critically important for establishing appropriate, population-specific cut-off values.

Conventional indices such as weight-for-age, height-for-age, and weight-for-height require accurate age determination, standardized equipment, and trained personnel, in contrast to circumference-based measurements, which offer a practical alternative or proxy measure for rapid screening and early identification of nutritionally vulnerable children. Although head circumference (HC) and mid-upper arm circumference (MUAC) have been increasingly used as proxy indicators of undernutrition, chest circumference (CC) remains relatively underutilized due to the absence of standardized, population-specific cut-off values, particularly among Indian preschool children. Therefore, deriving population-specific cut-off values is essential to improve screening diagnostic accuracy.

In this context, the objectives of the present study were to evaluate the reliability of HC, CC, and MUAC as screening measures and to determine suitable population-specific cut-offs for identifying undernutrition among preschool children of West Bengal, India. Therefore, the present study aims to attempt the age- and sex-specific optimal cutoff values for assessment of undernutrition among preschool children.

## Material and Methods

The present cross-sectional study was done on 1240 preschool children (625 boys and 615 girls) aged 2–5 years from 48 ICDS centres in Maynaguri Block, Jalpaiguri, West Bengal, India. All measurements were taken by the first author (A. B.). Anthropometric measurements were recorded following standard

international protocol [25]. The heights of the subjects were recorded with the help of an anthropometer to the nearest 0.10 cm. The weight of the children wearing minimal clothing and with bare feet was recorded using a portable digital weighing machine to the nearest 0.1 kg.

A total of five anthropometric measurements, including height, weight, HC, CC, and MUAC by standard procedures, were recorded.

Assessment of Undernutrition

The present study utilized the WHO 2006 guidelines to assess low weight for age, low height for age, low weight for height, low head circumference for age, and low mid-upper arm circumference for age. Where a Z-score value of less than – 2 SD is defined as undernutrition [26]. WHO Anthro Plus software was used to calculate the z-score.

Statistical Analysis

Data analysis was done on the Statistical Package for Social Science (SPSS) version 20. Descriptive statistics like mean and standard deviation were computed to understand the data distribution and variability. The t-test was utilized to analyze the significant sex difference in the mean anthropometric characteristics. One-way ANOVA was used to assess significant sex-combined-age variation. The Receiver Operating Characteristic (ROC) curve was constructed by plotting sensitivity (true positive rate) against 1 – specificity (false positive rate). The Youden Index (YI) was calculated as (sensitivity + specificity – 1). YI values and their corresponding cut-offs for different circumference measures. Receiver Operating Characteristics (ROC) to predict the most notable parameters for undernutrition and determine the cutoff values; ROC analysis was done on SPSS and MedCalc software.

Results

Table 1 shows the prevalence of undernutrition, such as underweight, was 22.40% in boys and 27.64% in girls; the prevalence of stunting was 23.20% in boys and 25.69% in girls; and the prevalence of wasting was 12.36% in boys and 14.4% in girls. Low head circumference for age was 23.36% in boys and 27.32% in girls, whereas low mid-upper arm circumference for age was 24.16% in boys and 26.67% in girls.

Table 1  
Sex-specific frequency and percentage distribution of anthropometric indices among studied children.

| Indices | Nutritional Status | Boys (%)    | Girls (%)   | Total (%)    |
|---------|--------------------|-------------|-------------|--------------|
| HCZ     | UN                 | 146 (23.36) | 168 (27.32) | 314 (25.32)  |
|         | N                  | 479 (76.64) | 447 (72.68) | 926 (74.68)  |
|         | Total              | 625 (100)   | 615 (100)   | 1240 (100)   |
| MUACZ   | UN                 | 151 (24.16) | 164 (26.67) | 315 (25.40)  |
|         | N                  | 474 (75.84) | 451 (73.33) | 925 (74.60)  |
|         | Total              | 625 (100)   | 615 (100)   | 1240 (100)   |
| WAZ     | UN                 | 140 (22.40) | 170 (27.64) | 310 (25.00)  |
|         | N                  | 485 (77.60) | 445 (72.36) | 930 (75.00)  |
|         | Total              | 625 (100)   | 615 (100)   | 1240 (100)   |
| HAZ     | UN                 | 145 (23.20) | 158 (25.69) | 303 (24.43)  |
|         | N                  | 480 (76.80) | 457 (74.31) | 937 (75.57)  |
|         | Total              | 625 (100)   | 615 (100)   | 1240 (100)   |
| WHZ     | UN                 | 95 (15.20)  | 76 (12.36)  | 171 (13.79)  |
|         | N                  | 530 (84.80) | 539 (87.64) | 1069 (86.21) |
|         | Total              | 625 (100)   | 615 (100)   | 1240 (100)   |

Sex-specific descriptive statistics, ranges, and mean anthropometric variables among children are presented in Table 2. The overall mean values of height, weight, head circumference, chest circumference, and mid-upper arm circumference are significantly higher in boys than girls. Table 2 describes the age- and sex-specific anthropometric characteristics among the studied children. All parameters increase with the advantage of age. Significant age variation was observed for all the parameters among both the sexes, where p < 0.001.

Table 2  
Age-specific mean and SD of anthropometric measures among studied children.

| Variables                           | Boys         |              |              |               |               |              |           | Girls        |              |              |              |               |              |           |
|-------------------------------------|--------------|--------------|--------------|---------------|---------------|--------------|-----------|--------------|--------------|--------------|--------------|---------------|--------------|-----------|
|                                     | Range        | 24–35        | 36–47        | 48–59         | 60–71         | 24–71        | F-value   | Range        | 24–35        | 36–47        | 48–59        | 60–71         | 24–71        | F-value   |
|                                     |              | N (156)      | N (157)      | N (167)       | N (145)       | N (625)      |           |              | N (143)      | N (167)      | N (191)      | N (114)       | N (615)      |           |
| HT                                  | 73.00–119.60 | 86.60 (5.36) | 93.84 (4.77) | 101.65 (4.96) | 108.57 (5.26) | 97.54 (9.58) | 530.27*** | 73.00–119.90 | 85.09 (4.95) | 91.68 (4.86) | 99.98 (5.05) | 106.73 (6.33) | 95.52 (9.28) | 438.06*** |
| WT                                  | 7.61–32.9    | 11.42 (1.82) | 13.06 (1.66) | 15.24 (2.94)  | 17.36 (3.36)  | 14.23 (3.36) | 156.49*** | 8.00–28.3    | 11.11 (1.87) | 12.38 (1.80) | 14.29 (2.26) | 16.78 (3.57)  | 13.50 (3.08) | 139.68*** |
| HC                                  | 41.90–54.50  | 46.68 (1.51) | 47.60 (1.35) | 48.35 (1.38)  | 49.32 (1.71)  | 47.97 (1.77) | 85.01***  | 42.30–55.9   | 45.95 (1.39) | 46.74 (1.64) | 47.30 (1.37) | 48.07 (1.68)  | 46.98 (1.67) | 45.62***  |
| CC                                  | 41.20–72.00  | 47.53 (2.38) | 49.40 (2.22) | 51.70 (3.94)  | 53.96 (3.70)  | 50.61 (3.65) | 117.51*** | 40.70–67.5   | 47.37 (2.64) | 48.17 (3.13) | 50.13 (3.02) | 52.83 (4.54)  | 49.46 (3.82) | 59.40***  |
| MUAC                                | 10.80–23.00  | 13.68 (1.16) | 14.08 (0.92) | 14.80 (1.59)  | 15.14 (1.69)  | 14.42 (1.68) | 35.22***  | 10.40–22.50  | 13.61 (1.27) | 14.03 (1.24) | 14.40 (1.20) | 15.17 (1.71)  | 14.26 (1.43) | 31.06***  |
| *p < 0.05; **p < 0.001; ***p < 0.00 |              |              |              |               |               |              |           |              |              |              |              |               |              |           |

Table 3 describes the age-specific anthropometric characteristics among normal and undernourished boys. Significant age variation was observed for all the parameters among normal and undernourished boys where  $p < 0.001$ . Age-specific mean difference was observed between normal and undernourished boys in all the measures where  $p < 0.05$ .

Table 3  
Age-specific mean (SD) anthropometric variables among undernourished and normal boys.

| Variables                            |    | 24–35           | 36–47           | 48–59            | 60–71           | 24–71             | F         |
|--------------------------------------|----|-----------------|-----------------|------------------|-----------------|-------------------|-----------|
|                                      |    | N (UN-71; N-85) | N (UN-60; N-97) | N (UN-46; N-121) | N (UN-53; N-92) | N (UN-230; N-395) |           |
| HT (cm)                              | UN | 83.18 (4.63)    | 90.19 (4.19)    | 96.87 (4.76)     | 105.42 (5.79)   | 92.87 (9.68)      | 229.61*** |
|                                      | N  | 89.45 (4.14)    | 96.10 (3.57)    | 103.46 (0.94)    | 110.38 (3.94)   | 100.25 (8.42)     | 508.12*** |
|                                      | t  | -8.837***       | -9.064***       | -8.469***        | -5.529***       | -9.623***         | 173.44*** |
| WT (kg)                              | UN | 10.16 (0.98)    | 11.63 (0.99)    | 13.01 (1.18)     | 14.93 (1.58)    | 12.21 (2.15)      | 106.58*** |
|                                      | N  | 12.47 (1.69)    | 13.94 (1.35)    | 16.10 (2.97)     | 18.76 (3.32)    | 15.41 (3.38)      | 26.85***  |
|                                      | t  | -10.572***      | -12.272***      | -9.594***        | -9.350***       | -14.403***        | 60.37***  |
| HC (cm)                              | UN | 46.32 (1.58)    | 47.10 (1.23)    | 47.90 (1.03)     | 48.41 (1.46)    | 47.31 (1.59)      | 70.35***  |
|                                      | N  | 46.98 (1.38)    | 47.92 (1.34)    | 48.52 (1.46)     | 49.84 (1.63)    | 48.35 (1.76)      | 78.27***  |
|                                      | t  | -2.727**        | -3.909***       | -3.045**         | -5.435***       | -7.488***         | 18.08***  |
| CC (cm)                              | UN | 46.38 (1.72)    | 47.97 (1.85)    | 49.14 (2.12)     | 51.48 (2.28)    | 48.52 (2.73)      | 24.72***  |
|                                      | N  | 48.49 (2.44)    | 50.28 (1.97)    | 52.68 (4.04)     | 55.38 (3.62)    | 51.82 (4.05)      | 78.275*** |
|                                      | t  | -6.730***       | -7.391***       | -7.315***        | -7.933***       | -12.104***        |           |
| MUAC (cm)                            | UN | 13.08 (0.83)    | 13.80 (0.83)    | 13.85 (0.79)     | 14.07 (0.78)    | 13.65 (0.90)      | 18.081*** |
|                                      | N  | 14.19 (1.16)    | 14.26 (0.94)    | 15.16 (1.67)     | 15.75 (1.77)    | 14.87 (1.57)      | 24.719*** |
|                                      | t  | -6.926***       | -3.252**        | -6.826***        | -7.802***       | -12.300***        |           |
| *p < 0.05; **p < 0.001; ***p < 0.001 |    |                 |                 |                  |                 |                   |           |

Table 4 describes the age-specific anthropometric characteristics among normal and undernourished girls. Significant age variation was observed for all the parameters among normal and undernourished girls, where  $p < 0.001$ . An age-specific mean difference was observed between normal and undernourished girls in all the measures where  $p < 0.001$ .

Table 4  
Age-specific mean (SD) anthropometric variables among undernourished and normal girls

| Variables                            |    | 24–35<br>N (UN-52; N-91) | 36–47<br>N (UN-80; N-87) | 48–59<br>N (UN-67; N-124) | 60–71<br>N (UN-41; N-73) | 24–71<br>N (UN- 240; N-375) | F         |
|--------------------------------------|----|--------------------------|--------------------------|---------------------------|--------------------------|-----------------------------|-----------|
| HT (cm)                              | UN | 80.50 (3.85)             | 88.62 (4.24)             | 96.04 (4.37)              | 102.44 (6.12)            | 91.29 (8.71)                | 210.77*** |
|                                      | N  | 87.71 (3.34)             | 94.50 (3.52)             | 102.11 (4.01)             | 109.14 (5.07)            | 98.22 (8.16)                | 456.49*** |
|                                      | t  | -11.306***               | -9.685***                | -9.427***                 | -5.969***                | -9.659***                   | 138.24*** |
| WT (kg)                              | UN | 9.50 (0.82)              | 11.27 (1.13)             | 12.48 (1.27)              | 14.15 (1.34)             | 11.71 (1.90)                | 111.00*** |
|                                      | N  | 12.04 (1.67)             | 13.41 (1.68)             | 15.27 (2.07)              | 18.26 (3.58)             | 14.64 (3.15)                | 19.19***  |
|                                      | t  | -12.137***               | -9.699***                | -11.507***                | -8.743***                | -14.324***                  | 33.62***  |
| HC (cm)                              | UN | 45.17 (1.34)             | 46.47 (1.39)             | 46.72 (1.23)              | 47.05 (1.38)             | 46.36 (1.48)                | 30.87***  |
|                                      | N  | 46.40 (1.22)             | 46.98 (1.82)             | 47.61 (1.35)              | 48.64 (1.57)             | 47.37 (1.67)                | 54.06***  |
|                                      | t  | -5.436***                | -2.023*                  | -4.557***                 | -5.611***                | -7.833***                   | 20.72***  |
| CC<br>(cm)                           | UN | 46.02 (1.79)             | 46.82 (2.33)             | 48.06 (1.81)              | 49.77 (2.01)             | 47.50 (2.38)                | 20.40***  |
|                                      | N  | 48.15 (2.73)             | 49.41 (3.26)             | 51.26 (2.95)              | 54.55 (4.67)             | 50.71 (4.03)                | 54.059*** |
|                                      | t  | -5.611***                | -5.918***                | -9.245***                 | -7.558***                | -12.414***                  |           |
| MUAC (cm)                            | UN | 12.65 (0.96)             | 13.46 (1.06) ()          | 13.63 (0.89)              | 14.19 (0.87)             | 13.46 (1.08)                | 20.721*** |
|                                      | N  | 14.16 (1.09)             | 14.54 (1.17)             | 14.82 (1.14)              | 15.71 (1.83)             | 14.77 (1.40)                | 20.399*** |
|                                      | t  | -8.528***                | -6.242***                | -7.953***                 | -5.976***                | -13.058***                  |           |
| *p < 0.05; **p < 0.001; ***p < 0.001 |    |                          |                          |                           |                          |                             |           |

Table 5 describes the binary logistic regression (BLR) analysis that was conducted, and the resulting Wald statistics and R<sup>2</sup> values were examined to identify the most effective predictor model. The CC appears to be a better predictor in terms of Wald statistics among boys (88.67 vs. 87.50) for WAZ and HAZ, but MUAC has the highest predictive value (42.73) for WHZ. Whereas among girls, MUAC appears to be a better predictor in terms of Wald statistics (125.36 vs. 37.71) for WAZ and WHZ, but CC has the highest predictive values for HAZ. The values of the coefficient of determination (R<sup>2</sup>) were observed to be higher in CC (WAZ 0.30 vs HAZ 0.29) and MUAC for WHZ (0.19) among boys. Whereas among girls, (R<sup>2</sup>) was observed to be higher in MUAC (WAZ 0.49 vs WHZ 0.19) and CC for HAZ 0.18.

Table 5  
Binary Logistic Regression analysis to predict the anthropometric indices among studied children

| <b>Boys</b>                          |           |          |       |       |         |                |       |
|--------------------------------------|-----------|----------|-------|-------|---------|----------------|-------|
| Undernutrition                       | Variables | Constant | B     | S.E.B | Wald    | R <sup>2</sup> | p     |
| WAZ                                  | HC        | -21.584  | 0.479 | 0.069 | 48.796  | 0.139          | 0.000 |
|                                      | CC        | -20.249  | 0.440 | 0.047 | 88.661  | 0.302          | 0.000 |
|                                      | MUAC      | -14.591  | 1.132 | 0.125 | 82.329  | 0.269          | 0.000 |
| HAZ                                  | HC        | -17.949  | 0.402 | 0.064 | 38.868  | 0.106          | 0.000 |
|                                      | CC        | -19.634  | 0.422 | 0.045 | 87.500  | 0.292          | 0.000 |
|                                      | MUAC      | -9.080   | 0.729 | 0.104 | 49.512  | 0.151          | 0.000 |
| WHZ                                  | HC        | -9.164   | 0.228 | 0.068 | 11.234  | 0.033          | 0.001 |
|                                      | CC        | -6.870   | 0.172 | 0.038 | 20.648  | 0.068          | 0.000 |
|                                      | MUAC      | -11.633  | 0.958 | 0.130 | 42.728  | 0.191          | 0.000 |
| <b>Girls</b>                         |           |          |       |       |         |                |       |
| Undernutrition                       | Variables | Constant | B     | S.E.B | Wald    | R <sup>2</sup> | p     |
| WAZ                                  | HC        | -20.407  | 0.457 | 0.066 | 48.002  | 0.128          | 0.000 |
|                                      | CC        | -26.031  | 0.559 | 0.055 | 103.060 | 0.368          | 0.000 |
|                                      | MUAC      | -24.854  | 1.872 | 0.167 | 125.357 | 0.494          | 0.000 |
| HAZ                                  | HC        | -19.399  | 0.438 | 0.067 | 43.312  | 0.117          | 0.000 |
|                                      | CC        | -14.190  | 0.314 | 0.041 | 57.991  | 0.184          | 0.000 |
|                                      | MUAC      | -7.695   | 0.626 | 0.092 | 46.660  | 0.136          | 0.000 |
| WHZ                                  | HC        | -8.183   | 0.217 | 0.078 | 7.705   | 0.025          | 0.006 |
|                                      | CC        | -11.555  | 0.279 | 0.052 | 29.177  | 0.115          | 0.000 |
|                                      | MUAC      | -11.053  | 0.947 | 0.134 | 37.709  | 0.195          | 0.000 |
| *p < 0.05; **p < 0.001; ***p < 0.001 |           |          |       |       |         |                |       |

The comparison of ROC-AUC to ascertain the dependency and appropriateness of HC, CC, and MUAC as screening measures of underweight, stunting, and wasting (Table 6). The result shows that ROC-AUC analysis was performed to ascertain the YI, associated criterion, and appropriateness of HC, CC, and MUAC described against various anthropometric indices. The result shows that for underweight children, the MUAC cut-off was observed to be 13.9 cm, with the highest YI being 0.57 among girls. For stunted children, the CC cut-off was observed to be 48.4 cm, with the highest YI being 0.48 among boys, and for wasted children, the MUAC cut-off was observed to be 13.9 cm, with the highest YI being 0.39 among boys.

ROC curves identify the most effective circumference for the prediction of undernutrition. In the case of underweight (WAZ), CC for boys has the highest AUC value (0.81), and MUAC for girls has the highest AUC value (0.88). In the case of stunting (HAZ), CC for both sexes has the highest AUC value (0.79 vs. 0.74). In the case of wasting (WHZ), MUAC of both sexes has the highest AUC value (0.70 vs. 0.75) (Table 6).

For the prediction of underweight children, CC has the highest YI values for boys (0.53) and girls (0.51). For the prediction of stunted children, CC has the highest YI values for boys (0.48) and girls (0.41). For the prediction of wasted children, MUAC has the highest YI values for boys (0.39) and girls (0.32) in Table 6.

Optimal cut-off values derived from the Youden Index suggested HC thresholds ranging from 45.5 cm to 47.9 cm, MUAC thresholds ranging from 13.4 to 14.0 cm, and CC thresholds ranging from 48.0 to 49.3 cm, depending on sex and nutritional index.

Table 6  
ROC analysis by sex groups for prediction of undernutrition among studied children

| Variables | Sex   | AUC  | SE   | 95% CI |       | Asymptotic Sig | Youden Index   |                      | Sen (%) | Spe (%) |
|-----------|-------|------|------|--------|-------|----------------|----------------|----------------------|---------|---------|
|           |       |      |      | Lower  | Upper |                | Youden Index J | Associated criterion |         |         |
| WAZ       |       |      |      |        |       |                |                |                      |         |         |
| HC        | Boys  | 0.70 | 0.02 | 0.65   | 0.74  | 0.000          | 0.32           | > 47.9               | 54.46   | 76.43   |
|           | Girls | 0.68 | 0.02 | 0.63   | 0.72  | 0.000          | 0.26           | > 46.6               | 62.02   | 64.12   |
| CC        | Boys  | 0.81 | 0.02 | 0.77   | 0.85  | 0.000          | 0.53           | > 48.7               | 78.76   | 75.00   |
|           | Girls | 0.83 | 0.02 | 0.79   | 0.86  | 0.000          | 0.51           | > 48.0               | 72.82   | 78.24   |
| MUAC      | Boys  | 0.79 | 0.02 | 0.75   | 0.83  | 0.000          | 0.47           | > 13.9               | 73.61   | 73.57   |
|           | Girls | 0.88 | 0.01 | 0.85   | 0.90  | 0.000          | 0.57           | > 13.9               | 72.58   | 84.71   |
| HAZ       |       |      |      |        |       |                |                |                      |         |         |
| HC        | Boys  | 0.67 | 0.02 | 0.62   | 0.72  | 0.000          | 0.26           | > 47.4               | 64.58   | 61.38   |
|           | Girls | 0.67 | 0.02 | 0.62   | 0.72  | 0.000          | 0.24           | > 46.6               | 61.05   | 63.29   |
| CC        | Boys  | 0.79 | 0.02 | 0.75   | 0.83  | 0.000          | 0.48           | > 48.4               | 80.21   | 67.59   |
|           | Girls | 0.74 | 0.02 | 0.70   | 0.78  | 0.000          | 0.41           | > 48.7               | 59.74   | 81.01   |
| MUAC      | Boys  | 0.71 | 0.02 | 0.67   | 0.75  | 0.000          | 0.35           | > 14.0               | 66.87   | 68.28   |
|           | Girls | 0.69 | 0.02 | 0.64   | 0.74  | 0.000          | 0.29           | > 13.4               | 79.65   | 49.37   |
| WHZ       |       |      |      |        |       |                |                |                      |         |         |
| HC        | Boys  | 0.60 | 0.03 | 0.54   | 0.66  | 0.002          | 0.18           | > 46.7               | 80.94   | 35.79   |
|           | Girls | 0.59 | 0.03 | 0.52   | 0.66  | 0.011          | 0.15           | > 45.5               | 83.67   | 31.58   |
| CC        | Boys  | 0.65 | 0.03 | 0.60   | 0.71  | 0.000          | 0.25           | > 49.3               | 63.77   | 61.05   |
|           | Girls | 0.71 | 0.03 | 0.65   | 0.76  | 0.000          | 0.31           | > 49.1               | 49.35   | 81.58   |
| MUAC      | Boys  | 0.75 | 0.03 | 0.70   | 0.81  | 0.000          | 0.39           | > 13.9               | 69.06   | 70.53   |
|           | Girls | 0.80 | 0.02 | 0.75   | 0.84  | 0.000          | 0.32           | > 13.6               | 65.02   | 63.77   |

## Discussion

The present study observed the distinct sexual dimorphism in anthropometric measures, and circumferences increased with the advantage of age, showing sexual dimorphism. Mean anthropometric measures were significantly higher among children with normal nutritional status compared to children who were undernourished. Statistically significant age variations in mean anthropometric parameters were observed between undernourished and normal children among boys and girls (Tables 3 & 4). In the present study, girls had higher nutritional deficiency and growth failure based on low HC, supporting previous findings [4, 6–9, 27], and as per MUAC, similar to previous findings [12, 14, 28]. Biologically, girls have different fat distribution patterns, which make deficiency more visible in terms of circumference-based indices such as HC and MUAC [3].

In the present study an attempt has been made to observe the reliability and acceptability of circumference-based parameters like CC as a valid alternative to conventionally used measures like MUAC and HC for nutritional assessment and to estimate the sex-specific cutoff among preschool children. The present investigation provides comprehensive evidence on the utility of circumference-based anthropometric measures HC, CC, and MUAC for screening undernutrition among children. The BLR analysis showed that CC has relatively better predictive values to determine underweight and stunting, whereas MUAC has better accuracy to predict wasting among children, as evidenced by higher wald statistics and coefficients of determination ( $R^2$ ) (Table 5). This finding is noteworthy because CC has traditionally received less attention compared to HC and MUAC. The sex-specific CC cut-off values enhance the applicability of these measures in community-based settings, allowing for more accurate and context-specific identification of nutritionally vulnerable children.

Studies have suggested the use of the combination of HC and CC ratios as an index of growth retardation prediction among very low birth weight infants [29] and to detect foetal growth restriction in term infants [30].

The present study utilized circumference-based measures such as HC, CC, and MUAC for predicting growth faltering and nutritional deficiency, which demonstrated age-and-sex-combined ROC (Fig. 1), sex-combined age-specific ROC (Fig. 2), age-specific ROC for boys (Fig. 3), and age-specific ROC for girls (Fig. 4).

The present study demonstrates that circumference-based anthropometric measures are effective screening tools for identifying undernutrition among Indian preschool children. CC emerged as a robust predictor of chronic undernutrition (underweight and stunting), while MUAC was more sensitive in

detecting acute undernutrition (wasting).

The present findings further validate MUAC as a reliable indicator and extend existing knowledge by establishing CC as a valuable complementary measure. The present study underscores the importance of incorporating multiple circumference-based indicators rather than relying on a single anthropometric measure. The combined use of CC and MUAC can improve early detection of both chronic and acute forms of undernutrition in preschool children.

The result of the ROC AUC analysis for cutoff estimations shows that HC > 47.9 cm for boys vs. >46.6 cm for girls among underweight children, HC > 47.4 cm for boys vs. >46.6 cm for girls among stunted children, and HC > 46.7 cm for boys vs. >45.5 cm for girls among wasted children.

The ROC AUC analysis for cutoff estimations shows that CC > 48.7 cm for boys vs. >48.0 cm for girls among underweight children, CC > 48.4 cm for boys vs. >48.7 cm for girls among stunted children, and CC > 49.3 cm for boys vs. >49.1 cm for girls among wasted children.

The ROC AUC analysis for cut-off estimations shows that MUAC is > 13.9 cm for boys vs. >13.9 cm for girls for underweight children, MUAC is > 14.0 cm for boys vs. >13.4 cm for girls among stunted children, and MUAC is > 13.9 cm for boys vs. >13.6 cm for girls among wasted children.

Zhou et al. [17] reported MUAC of > 14.35 cm in severe wasting, > 14.55 cm in moderate wasting, and > 15.35 cm in mild wasting, whereas > 14.35 cm for severely underweight and > 15.5 cm for moderate underweight children were reported as the best cut-off values to determine undernutrition among children having cerebral palsy in China.

A study reported on Indian children reported by Sinha et al. [20] to observe MUAC thresholds for screening wasting and severe wasting. The study reveals that the MUAC cut-off was 13.8 cm for children 24–59, whereas the appropriate MUAC cut-offs were 13.8 cm for children 6–59 months (sensitivity: 0.82, specificity: 0.69, AUC: 0.84; 95% CI: 0.82, 0.86).

A study reveals WHZ and MUAC have a positive linear relationship for the prediction of acute malnutrition among children reported by Jasani et al. [24]. MUAC was a very important tool for screening of undernutrition with specificity and sensitivity (Mahapatra & Bose [3]).

Several researchers reported a similar significant association of MUAC with undernutrition among children of various regions. Assessment of acute malnutrition comparison through MUAC measures among Bangladeshi children was done by Hossain et al. [21] and Haque et al. [23]. Assessment of WAZ, HAZ, and WHZ by MUAC among children having cerebral palsy in China done by Zhou et al. [17] and in Turkey done by Topçu et al. [18]; MUAC cut-off prediction done to identify acute malnutrition defined by WHZ among children of Niger reported by Marshall et al. [22]; and MUAC and WHZ correlation with ROC curve analysis done among Vietnamese children by Luu et al. [16], where the AUC value indicates the MUAC was a good predictor of malnutrition. Prediction of malnutrition among under-five children of India reported by Sachdeva et al. [31] and Sri Lankan children by Shinsugi et al. [15] based on MUAC. ROC curve analysis was also utilised to detect the anthropometric indices from MUAC measures in previous research done among children of other studies by several scholars such as Shinsugi et al. [15]; Zhou et al. [17]; Hossain et al. [21]; Marshall et al. [22]; Sachdeva et al. [31]. A study reported on children of Uttar Pradesh; the diagnostic test accuracy of MUAC for severe wasting was excellent, where the optimal MUAC cut-off to detect severe wasting was 135 mm reported by Kapil et al. [19]. Previous findings are compatible with the present results, where MUAC has the highest ability for the prediction of wasting. Sensitivity and specificity assessment of MUAC for SAM was reported in previous reports on children [32, 33]. Based on the present findings, the AUC of MUAC for WHZ prediction was 0.75 (CI 0.70–0.81) for boys and AUC 0.80 (CI 0.75–0.84) for girls, supporting the previous research findings [3, 15, 17].

HC has the predictive potential to measure cognitive impairment and undernutrition during the early stage of life. Head circumference had excellent ROC discrimination for identifying low birth weight among children of Nepal observed by Sreeramareddy et al. [34]. A study reveals it was possible to use head circumference to identify chronic malnutrition in critically ill children of Wisconsin [35]. The study reported on Hill Korwa children, where ROC curve, specificity, and sensitivity analyses were done to predict nutritional status from head circumference and chest circumference [36]. A study found HC, CC, and MUAC as surrogates for the prediction of low birth weight [37].

Study on Tanzanian children reported CC and MUAC correlated significantly with birth weight, and CC was recommended as the first stage screening method of choice for LBW children [38]. CC and HC were found to be better surrogate measurements to identify low birth weight children of Ethiopia [39]. In the present study CC has shown a consistent decline among stunted, and underweight children and demonstrates comparable sensitivity to conventional indicators such as HC and MUAC.

The rationale for using ROC lies in its ability to determine optimal cut-off values by balancing sensitivity and specificity. Evidence regarding the use of HC and CC for the prediction of undernutrition among Indian children is limited. There is unavailability of universally standardized CC cut-offs for undernutrition screening in preschool children globally as well as in India.

Hence, although the outcome of any population-specific and clinical studies could be improved by using simple and appropriate anthropometric variables such as HC, CC, and MUAC, larger studies are needed to validate the results. The present study contributes robust empirical evidence supporting the inclusion of CC as a complementary anthropometric indicator for nutritional assessment among preschool children.

The present study has its limitation due to cross-sectional in nature, with a small sample size, and the present finding may be generalizable to the regional studies but not to the state or country level. This study was unable to find the associated socioeconomic and dietary factors with undernutrition.

## Conclusion

The present study reported MUAC-based undernutrition slightly higher than the HC-based undernutrition. CC emerged as a suitable predictor of underweight and stunted children, whereas MUAC emerged as a better predictor of wasting. CC and MUAC are reliable, low-cost screening tools for assessing

undernutrition among preschool children. The population-specific cut-offs proposed in this study can enhance early detection and facilitate targeted nutritional interventions in community and programmatic settings. Adoption of HC, MUAC, and CC in community programmes like ICDS could facilitate early identification of undernutrition and contribute to improved nutrition and optimal growth among children.

## Declarations

### Acknowledgement

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### Conflict of Interest

There is no conflict of interest.

### Ethical Approval

The study protocol was approved by the Institutional Ethical Committee of University of North Bengal, reference number 3390/R-2023 dated 11/08/2023 and was conducted in accordance with the Helsinki ethical guidelines.

### Consent to participate

Verbal informed consent was obtained from the mothers of the studied children prior to the participation in the study. The purpose and procedures of the study were explained to the mothers in an understandable language. The verbal consent process was witnessed by the respective Anganwadi workers. Participation was entirely voluntary.

### Consent for publication

Not applicable.

### Clinical trial registration number

Not applicable

### Authors Contribution

A.B.- Conceptualization, methodology, investigation, data collection, data analysis, visualization, writing original draft, and writing review and editing.

A.K.- Methodology, supervision, interpretation of results, writing, review and editing.

N.M.- Conceptualization, Methodology, supervision, statistical analysis, interpretation of results, writing and review and editing.

K.B.- Supervision, interpretation of results and discussion, writing, review and editing.

### Data availability

The datasets generated and/or analysed during the current study are not publicly available because they contain information relating to individual child participants but are available from the corresponding author on reasonable request, subject to applicable ethical and institutional restrictions.

## References

1. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*. 2013;382(9890):427-51. doi:10.1016/S0140-6736(13)60937-X.
2. UNICEF. UNICEF–The World Bank joint child malnutrition estimates: levels and trends, 2019 edition. UNICEF Data; 2019. Available from: <https://data.unicef.org/resources/jme/>
3. Mahapatra B, Bose K. Growth and nutritional status of tribal preschool children: an assessment based on body circumferences. *Mankind Q*. 2025;66(1):183-99.
4. Maiti S, Ali KM, Ghosh D. Assessment of head circumference among pre-school children of Midnapore town, West Bengal using WHO recommended cut-off points. *Int J Prev Med*. 2012;3(10):742-4.
5. Sukanya BV, Baragundi MC, Surekharani CS, Shailaja P, Gadwal R. Assessment of nutritional status of preschool children using head circumference. *Int J Curr Med Appl Sci*. 2014;4:72-5.

6. Tigga PL, Mondal N, Sen J. Head circumference as an indicator of undernutrition among tribal preschool children aged 2–5 years of Bengal, India. *Hum Biol Rev.* 2016;5(1):17-33.
7. Giri SP, Biswas S, Bose K. Head circumference based nutritional status of rural Bengalee preschool children from Sagar Island, West Bengal, India. *Mankind Q.* 2018;58(4):599-610.
8. Sharma J, Mondal N. Assessment of undernutrition using head circumference-for-age among Karbi preschool children of Karbi Anglong, Assam, India. *J Life Sci.* 2019;11(1-2):7-16. doi:10.31901/24566306.2019/11.1-2.238.
9. Biswas A, Khatun A. Assessment of nutritional status by head circumference among rural preschool children of Jalpaiguri, West Bengal, India. *Online J Health Allied Sci.* 2023;22(3):2.
10. Maiti S, De D, Ali KM, Ghosh A, Ghosh A, Paul S. Evaluation of nutritional status by mid-upper arm circumference amongst affluent children. *J Nepal Paediatr Soc.* 2012;32(2).
11. Singh PK, Mukherjee B. Assessment of nutritional status by mid upper arm circumference (MUAC) among rural children of Katihar District in Kosi Region of Bihar. *J Evol Med Dent Sci.* 2015;4(22):3823-9.
12. Khan I, Parvin N. Nutritional assessment based on mid upper arm circumference of the Hill Korwas under five years of age in Sarguja District, Chhattisgarh, India. *Int J Pharm Biol Sci.* 2018;8(4):220-6.
13. Giri SP, Biswas S, Bose K. Assessment of nutritional status using mid-upper arm circumference among Bengalee preschool children of Sagar Island, South 24 Parganas, West Bengal, India. *J Life Sci.* 2019;11(1-2):1-6.
14. Biswas A, Khatun A. Mid upper arm circumference based nutritional assessment and its determinants among ICDS beneficiaries. *Online J Health Allied Sci.* 2024;23(2):2.
15. Shinsugi C, Gunasekara D, Takimoto H. Use of mid-upper arm circumference (MUAC) to predict malnutrition among Sri Lankan schoolchildren. *Nutrients.* 2020;12(1):168.
16. Luu TMT, Vu HN, Vo ATT, Tran LT. Correlation between MUAC z-score and the anthropometric indexes, weight and height, in the assessment of the nutritional status of pediatric inpatients. *World Acad Sci J.* 2024;6(4):36.
17. Zhou H, Peng T, Wei M, Zhang J, Zhao Y, Le W, et al. Validity and predictability of mid-upper arm circumference for nutrition screening in outpatient preschoolers with cerebral palsy. *Front Nutr.* 2025;12:1609032.
18. Topçu U, Lazoğlu Ç, Aslan C, Güney AZ, Kavcar Z, Coşkun O. Use of mid-upper arm circumference band in wasting detection in children with cerebral palsy in Türkiye. *Children (Basel).* 2025;12(8):1002.
19. Kapil U, Pandey RM, Bansal R, Pant B, Varshney AM, Yadav CP, et al. Mid-upper arm circumference in detection of weight-for-height z-score below -3 in children aged 6–59 months. *Public Health Nutr.* 2018;21(10):1794-9.
20. Sinha RK, Kumar P, Seth A. Optimizing mid-upper arm circumference (MUAC) thresholds for screening wasting and severe wasting in children aged 6–59 months in community settings in India. *Indian J Pediatr.* 2025;92:1-6.
21. Hossain MI, Ahmed T, Arifeen SE, Billah SM, Faruque ASG, Islam MM, et al. Comparison of mid-upper arm circumference and weight-for-height z score for assessing acute malnutrition in Bangladeshi children aged 6–60 months: an analytical study. *Am J Clin Nutr.* 2017;106(5):1232-7.
22. Marshall SK, Monárrez-Espino J, Eriksson A. Performance of mid-upper arm circumference to diagnose acute malnutrition in a cross-sectional community-based sample of children aged 6–24 months in Niger. *Nutr Res Pract.* 2019;13(3):247-55.
23. Haque MA, Choudhury N, Ahmed ST, Farzana FD, Ali M, Naz F, et al. Does a child's mid-upper arm circumference-for-age z-score represent another nutritional indicator of childhood malnutrition status? *Matern Child Nutr.* 2022;18(4):e13404.
24. Jasani KM, Gosalia VV, Misra SV. Diagnostic accuracy of mid-upper arm circumference for the detection of acute malnutrition among children aged 6–60 months: a diagnostic accuracy study. *J Res Health Sci.* 2024;24(2):e00612. doi:10.34172/jrhs.2024.147.
25. Lohman TG, Roche AF, Martorell R, editors. Anthropometric standardization reference manual. Champaign (IL): Human Kinetics Books; 1988.
26. World Health Organization. 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. Geneva: World Health Organization; 2006.
27. Kshatriya GK, Roy PK, Biswas S, Chanak M, Bose K. Evaluation of nutritional status using head circumference among Bhil, Dhodia and Kinnaura tribal preschool children, India. *Indian J Child Health.* 2024;11:1-8.
28. Kshatriya GK, Roy PK, Chanak M, Biswas S, Bose K. Nutritional assessment based on mid-upper arm circumference among tribal preschool children of three distinct ecological zones of India. *J Anthropol Surv India.* 2025;74(1):7-23.
29. Shoji H, Murano Y, Saitoh Y, Ikeda N, Ohkawa N, Nishizaki N, et al. Use of head and chest circumference ratio as an index of fetal growth retardation in preterm infants. *Nutrients.* 2022;14(22):4942.
30. Saito H, Murano Y, Ashikawa S, Yoneoka D, Shoji H, Nakazawa T, et al. The head circumference to chest circumference ratio provided an easy way to detect foetal growth restriction in term infants. *Acta Paediatr.* 2024;113(1):67-71.
31. Sachdeva S, Dewan P, Shah D, Malhotra RK, Gupta P. Mid-upper arm circumference v. weight-for-height z-score for predicting mortality in hospitalized children under 5 years of age. *Public Health Nutr.* 2016;19(14):2513-20.
32. Abitew DB, Yalew AW, Bezabih AM, Bazzano AN. Comparison of mid-upper-arm circumference and weight-for-height z-score in identifying severe acute malnutrition among children aged 6–59 months in South Gondar Zone, Ethiopia. *J Nutr Metab.* 2021;2021:8830494.
33. Lambebo A, Mezemir Y, Tamiru D, Belachew T. Sensitivity and specificity of mid-upper arm circumference for assessment of severe acute malnutrition among children ages 6 to 59 months: systematic review and meta-analysis. *Nutrition.* 2023;107:111918.

34. Sreeramareddy CT, Chuni N, Patil R, Singh D, Shakya B. Anthropometric surrogates to identify low birth weight Nepalese newborns: a hospital-based study. *BMC Pediatr.* 2008;8(1):16.
35. Ochoa-Ramirez A, Kuhn EM, Sirinit J, Mikhailov TA. Head circumference as an indicator of nutritional status in critically ill children under 2 years of age. *OBM Integr Complement Med.* 2022;7(1):1-11.
36. Khan I, Nayak JK. Receiver operating characteristic (ROC) curves to identify anthropometric indices to predict nutritional status of the Hill Korwa children of Sarguja District, Chhattisgarh. *Int J Pharm Biol Sci.* 2019;9(1):283-8.
37. Sintayehu E, Sintayehu Y, Oumer A, Berhane A. Identification of anthropometric surrogate measurements and their cut-off points for the detection of low birth weight and premature newborn babies using ROC analysis. *J Nutr Sci.* 2023;12:e32.
38. Walraven GE, Mkanje RJ, van Roosmalen J, van Dongen PW, Dolmans WM. Chest circumference as a screening method for low birth weight in newborns in rural Tanzania. *Trop Geogr Med.* 1994;46(1):14-6.
39. Hadush MY, Berhe AH, Medhanyie AA. Foot length, chest and head circumference measurements in detection of low birth weight neonates in Mekelle, Ethiopia: a hospital based cross sectional study. *BMC Pediatr.* 2017;17(1):111.

## Figures

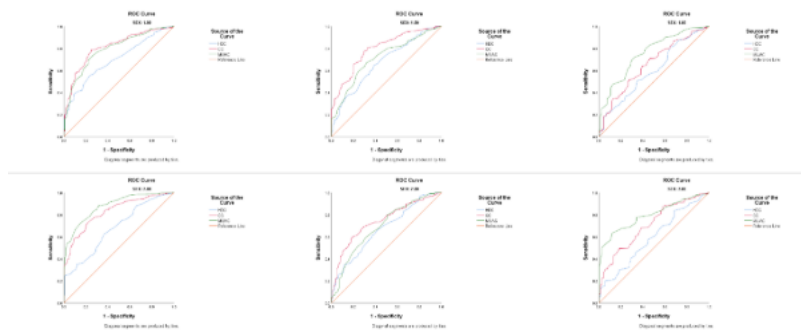


**Figure 1**

Age combined sex specific ROC curves for WAZ, HAZ and WHZ among studied children (Sex 1=boys and Sex 2=girls).

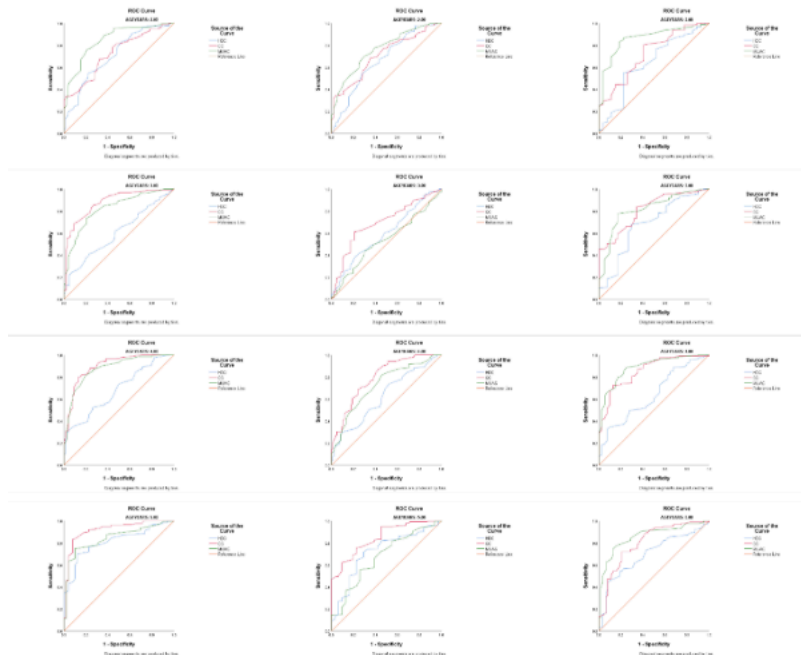


**Figure 2**

Sex combined age specific ROC curves for WAZ, HAZ and WHZ among studied children (Sex 1=boys and Sex 2=girls).

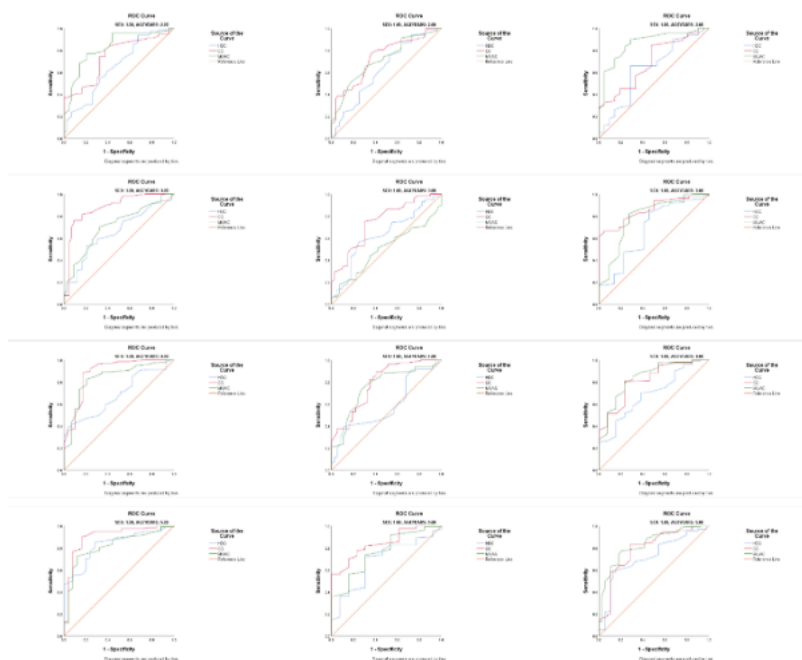


Figure 3

Age Specific ROC curves for WAZ, HAZ and WHZ among studied boys.

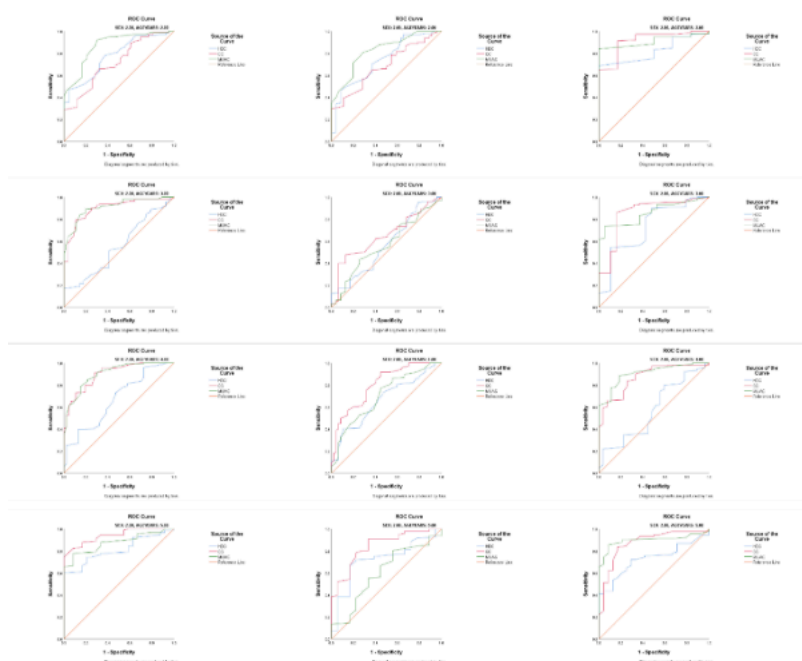


Figure 4

Age Specific ROC curves for WAZ, HAZ and WHZ among studied girls.