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Growth and Nutritional Status of Tribal Preschool Children: An Assessment Based on Body Circumferences

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Abstract

In India, undernutrition is the most prevalent health issue among tribal preschool children. The present study describes growth and nutritional status among tribal preschool children based on mid-upper arm circumferences (MUAC) and head circumference (HC). It utilizes the receiver operating characteristics (ROC) curve to determine cut-off points for body circumferences as a screening tool for growth and nutritional status. The present study surveyed 848 tribal preschool children aged 12-71 months from two districts of West Bengal, India. Undernutrition was assessed using WHO standard reference values of age and sex specific HC and MUAC z scores (< -2SD). The prevalence of undernutrition assessed by MUAC and head circumferences was 35.3% and 60.7%, respectively. The overall undernutrition prevalence is 70.9%, consisting of 45.8% with one type of undernutrition (MUAC or HC) and 25.1% with undernutrition on both measures. Body circumferences showed a higher mean value in healthy children compared to children with nutritional deficiencies, in both boys and girls. Boys had significantly higher mean body circumferences than girls. The study reveals that HC-based nutritional deficiencies are more prevalent than MUAC-based. Assessment of undernutrition using body circumferences and circumference-to-height ratios supports early detection of undernutrition and impaired growth status among tribal preschool children.

Keywords: Tribal nutrition, Preschool children, Growth, Nutrition, Body circumferences, Anthropometry

1 Introduction

In India, child undernutrition is a major health problem, particularly in tribal communities. Globally, malnutrition causes over 3.1 million child deaths annually, with one in every three under-five children being malnourished (Black et al., 2013; IFPRI, 2016). This malnutrition (under- and overnutrition) affects growth potential and future morbidity and mortality risks (Alderman et al., 2003). Undernutrition in India is a significant public health issue, which increases childhood mortality and morbidity (UNICEF, 2019). Under-five (0-5 years age) mortality rates are 34 per 1000 live births in India and 25 per 1000 in West Bengal (UNICEF, 2019). Undernutrition is a significant cause of child mortality in developing countries like India, with nearly half of preschool-aged deaths in low- and middle-income countries attributed to this issue (Black et al., 2013). In West Bengal, previous research indicates that approximately 50% of children experience various forms of undernutrition (Bose et al., 2008).

In India, head circumference (HC) and mid upper arm circumference (MUAC) are utilized in survey and screening programs to diagnose protein-energy malnutrition (Singh & Bisnoi, 2005). HC is a physical indicator of past nutritional status and brain or cognitive development among children (Rumsey & Rapoport, 1983). Neck circumference is a marker of malnutrition that assesses both undernutrition and obesity in children. Other circumferences like chest, thigh, and medial calf are useful indicators of nutritional status, but are rarely used due to lack of a standardized cut-off value. For these reasons, the present study attempts to provide an age- and sex-wise optimal cut-off value for assessing undernutrition among preschool children.

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Preschool children, particularly tribal children, are the most nutritionally vulnerable segment in communities. Preschool children in India are given low priority in both programs and policies (Planning Commission Report, 2007), although they have special nutritional requirements due to their growth and development (WHO, 1995). In India, mainly two government schemes are running to provide supplementary food for preschool children. One is Integrated Child Development Services (ICDS), which provides supplementary nutrition, health checkups, immunization, referral services, health and nutrition education, and preschool education through Anganwadi centers. Another is POSHAN Abhiyaan, which aims to reduce stunting, undernutrition, anemia, and low birth weight for children. A study in West Bengal found that only 47.3% of under-five tribal preschool children used ICDS services (Ray et al., 2000), highlighting the lack of access to food provided by Anganwadi centers, a trend that has been observed in other studies (Behera et al., 2024). A previous study in West Bengal observed that most parents are engaged in agricultural work during the day, limiting their time with their children. In general, grandmother and elder sister or brother take care of the child, including feeding them (Mahapatra et al., 2020). This is a serious gap, because ICDS is meant to be the backbone of nutrition support for preschool children in India.

In population-based studies, the anthropometric measurements used most frequently as indicators of undernutrition are low height for age, low weight for age and low weight for height, but low HC for age or low MUAC for age are rarely used (WHO, 1995). Very few studies addressed the nutritional status by using body circumferences among tribal children (Mondal, 2019; Tigga et al., 2016). Only some of these studies focus on West Bengal (Giri et al., 2018; Mahapatra, 2021; Maiti et al., 2012; Mandal & Bose, 2010). We assess undernutrition in preschool children through stunting, underweight, wasting, and thinness, using age- and sex-wise height, weight, and BMI. Similarly, we can assess undernutrition by using different circumferences. In the case of circumferences, only HC and MUAC have standard cut-off values provided by WHO. We cannot assess undernutrition from other circumferences due to lack of cut-off values.

2 Methods

2.1 Study design and participants

The present study was conducted on tribal preschool children aged 12–71 months. Three blocks were studied; these are Nayagram block, the most populated tribal block in the Jhargram district, and its nearest two blocks (Dantan I and Keshiary) of Paschim Medinipur district. This study focused on the most populous Santal and Bhumij tribes, which belong to the Austro-Asiatic (Munda) speaking tribes of West Bengal. The present study included children from agriculture-related households, excluding physically challenged children, those who failed inclusion criteria, and parents unwilling to participate.

The present study included 13 villages (Amda, Bhadra, Bhumijsai, Dudhe budhe, Dakshindiha, Joykrishnapur, Julko, Junbalda, Kamarchowki, Kanpur, Salbani, Sarisa, Talbandh) from the Keshiary block, 8 villages (Antri, Bahalia, Beldiha, Borah, Dhuriya, Manikara, Markandapur, Uchudiha) from the Dantan-I block, and 15 villages (Barpat, Begunadahi, Bhaliaghati, Gulfa, Hasimpur, Jadukatha, Jagannathpur, Jarka, Kadokatha, Khanamuri, Marapada, Pungiri, Singdhui, Talakuldihi, Tufuria) from the Nayagram block. We conducted the research from April 2018 to March 2019. The 2011 Census reported a population of 17,598 in Nayagram block, with 41.01% of preschool children belonging to tribal peoples. The Keshiary block had 16,984 children under five, with 34.25% of scheduled tribes. The Dantan I block had 20,209 children aged 0-5, with 16.38% belonging to tribal peoples. In the three blocks combined, the total number of tribal children was 16,169 (Census, 2011). The study used stratified random sampling to select 848 under-five children from Santal and Bhumij ethnic groups, with 95% confidence level, 50% population proportion, and a 3.3% margin of error.

2.2 Anthropometric data

The anthropometric measurements were conducted in accordance with standard procedures (Lohman et al., 1988). The departmental ethics committees provided the ethical clearance, and the study adhered to the Declaration of Helsinki's ethical guidelines (Touitou et al., 2004). Three kinds of anthropometric measurements were taken from each participant: height, weight, and several body circumferences. Weight was measured using digital weighing scales. The standing height was measured using an anthropometric rod, and the recumbent length was measured using an infantometer. Circumferences were measured using a measuring tape. The study participants provided six types of body circumferences (head circumference, neck circumference, mid upper arm circumference, chest circumference, thigh circumference, medial calf circumference) and six types of circumferences to height ratios (head to height ratio, neck to height ratio; mid upper arm circumference to height ratio; chest to height ratio; thigh to height ratio; medial calf to height ratio).

2.3 Assessments of undernutrition

The current study utilized the WHO 2006 guidelines to evaluate undernutrition using low HC for age (HCAZ) and low MUAC for age (MUACZ) z score (WHO, 2006). The WHO (2006) guidelines were used to calculate the Z-scores for two indices, with undernutrition defined as a value more than two standard deviations below the median (i.e., Z-score $<$ -2 SD) (WHO, 1995). The Z score was determined using the standard equation: Z score= $\frac{X-Median\ of\ WHO,\quad 2006}{SD\ of\ WHO,\quad 2006}$

'X' indicates the observed value of circumference. The study identified single and dual types of undernutrition, with single-undernourished children presenting with only one deficiency (HC or MUAC) and dual-undernourished children presenting with both. Low MUAC in children indicates poor nutritional status, while low head circumference indicates inadequate brain development, impacting their growth and development.

2.4 Statistical analysis

The data were analysed with SPSS version 27.0. The descriptive statistics were used to determine the statistical significance of group differences. This study used the Receiver Operating Characteristic (ROC) curve to predict the most notable parameter for dual types of undernutrition and determine the cut-off values.

3 Results

Tables 1 and 2 present the mean age- and sex-wise body circumferences and the differences in the circumference-to-height ratio. All body circumferences increased with increasing child age, and significant differences were observed ($p < .001$). However, mean values of circumference to height ratio decreased with increasing child age. In the case of body circumferences, boys show higher mean values than girls except for thigh circumference. Sex differences were statistically significant except for medial calf circumference. In circumference to height ratios, the chest, thigh, and medial calf show statistically significant sex differences.

Table 1: Table 1. Age wise mean body circumferences and circumferences to height ratios (mean ± SD) among the participants.

Anthropometric variables	12–23 ($n = 205$)	24–35 ($n = 179$)	36–47 ($n = 140$)	48–59 ($n = 180$)	60–71 ($n = 144$)	F test
Head circumference (HC)	43.41 ± 1.69	45.23 ± 1.64	46.08 ± 1.56	47.02 ± 1.43	47.18 ± 1.75	168.50^{***}
Neck circumference (NC)	20.44 ± 1.01	21.31 ± 1.16	21.73 ± 1.09	22.02 ± 0.96	22.31 ± 0.99	88.91^{***}
Mid upper arm circumference (MUAC)	12.53 ± 0.74	13.50 ± 0.85	13.52 ± 0.91	13.80 ± 0.92	13.87 ± 0.83	81.05^{***}
Chest circumference (CC)	42.93 ± 2.13	45.40 ± 2.37	46.97 ± 2.43	48.37 ± 2.16	49.20 ± 2.78	203.13^{***}
Thigh circumference (TC)	21.21 ± 1.55	22.13 ± 1.87	23.65 ± 2.10	24.50 ± 2.06	24.91 ± 2.01	123.35^{***}
Medial calf circumference (MCC)	15.69 ± 1.11	16.82 ± 1.15	17.63 ± 1.25	18.42 ± 1.37	18.76 ± 1.24	187.57^{***}
Head to height ratio (HHtR)	0.5820 ± 0.03	0.5395 ± 0.03	0.5010 ± 0.03	0.4753 ± 0.02	0.4513 ± 0.02	769.68^{***}
Neck to height ratio (NHtR)	0.2741 ± 0.02	0.2542 ± 0.02	0.2361 ± 0.01	0.2225 ± 0.01	0.2133 ± 0.01	542.17^{***}
MUAC to height ratio (AHtR)	0.1680 ± 0.01	0.1556 ± 0.01	0.1468 ± 0.01	0.1394 ± 0.01	0.1326 ± 0.01	352.04^{***}
Chest to height ratio (CHtR)	0.5754 ± 0.03	0.5413 ± 0.03	0.5102 ± 0.03	0.4885 ± 0.02	0.4704 ± 0.03	439.76^{***}
Thigh to height ratio (THtR)	0.2844 ± 0.02	0.2630 ± 0.02	0.2566 ± 0.02	0.2478 ± 0.02	0.2382 ± 0.02	129.26^{***}
Medial calf to height ratio (MCHtR)	0.2103 ± 0.01	0.2005 ± 0.01	0.1914 ± 0.01	0.1859 ± 0.01	0.1793 ± 0.01	163.02^{***}

Note. $* \ p < .05$, $** \ p < .01$, $*** \ p < .001$.

Table 2: Age-wise mean body circumferences and circumference-to-height ratios (mean ± SD) among the participants.

Anthropometric variables	12–23 ($n = 205$)	24–35 ($n = 179$)	36–47 ($n = 140$)	48–59 ($n = 180$)	60–71 ($n = 144$)	F test
Head circumference (HC)	43.41 ± 1.69	45.23 ± 1.64	46.08 ± 1.56	47.02 ± 1.43	47.18 ± 1.75	168.50^{***}
Neck circumference (NC)	20.44 ± 1.01	21.31 ± 1.16	21.73 ± 1.09	22.02 ± 0.96	22.31 ± 0.99	88.91^{***}
Mid upper arm circumference (MUAC)	12.53 ± 0.74	13.50 ± 0.85	13.52 ± 0.91	13.80 ± 0.92	13.87 ± 0.83	81.05^{***}
Chest circumference (CC)	42.93 ± 2.13	45.40 ± 2.37	46.97 ± 2.43	48.37 ± 2.16	49.20 ± 2.78	203.13^{***}
Thigh circumference (TC)	21.21 ± 1.55	22.13 ± 1.87	23.65 ± 2.10	24.50 ± 2.06	24.91 ± 2.01	123.35^{***}
Medial calf circumference (MCC)	15.69 ± 1.11	16.82 ± 1.15	17.63 ± 1.25	18.42 ± 1.37	18.76 ± 1.24	187.57^{***}
Head to height ratio (HHtR)	0.5820 ± 0.03	0.5395 ± 0.03	0.5010 ± 0.03	0.4753 ± 0.02	0.4513 ± 0.02	769.68^{***}
Neck to height ratio (NHtR)	0.2741 ± 0.02	0.2542 ± 0.02	0.2361 ± 0.01	0.2225 ± 0.01	0.2133 ± 0.01	542.17^{***}
MUAC to height ratio (AHtR)	0.1680 ± 0.01	0.1556 ± 0.01	0.1468 ± 0.01	0.1394 ± 0.01	0.1326 ± 0.01	352.04^{***}
Chest to height ratio (CHtR)	0.5754 ± 0.03	0.5413 ± 0.03	0.5102 ± 0.03	0.4885 ± 0.02	0.4704 ± 0.03	439.76^{***}

Table 2 (continued)

Anthropometric variables	12–23 ($n = 205$)	24–35 ($n = 179$)	36–47 ($n = 140$)	48–59 ($n = 180$)	60–71 ($n = 144$)	F test
Thigh to height ratio (THtR)	0.2844 ± 0.02	0.2630 ± 0.02	0.2566 ± 0.02	0.2478 ± 0.02	0.2382 ± 0.02	129.26^{***}
Medial calf to height ratio (MCHtR)	0.2103 ± 0.01	0.2005 ± 0.01	0.1914 ± 0.01	0.1859 ± 0.01	0.1793 ± 0.01	163.02^{***}

Note. $*\ p < .05$, $**\ p < .01$, $***\ p < .001$.

Table 3 shows the prevalence of undernutrition based on two types of circumferences among the tribal preschool children. Overall, MUAC and HC-based undernutrition was 35.3% (boys: 34.4 and girls: 36.1%) and 60.7% (boys: 59.3 and girls: 62.2%), respectively. Most of the children had one type of undernutrition (45.8%). Only 25.1% were undernourished on both measures, MUAC and HC. On both measures, girls experienced a marginally higher prevalence of growth and nutritional deficiencies than boys, but differences were not statistically significant. Figure 1 represents the HC and MUAC based growth and nutritional status among the studied tribal preschool children. The frequencies of undernutrition were 35.6% for HC only, 10.2% for MUAC only, and 25.1% for both conditions.

Table 3: **Table 3.** Sex-wise growth and nutritional status indicators among the studied preschool children. Numbers with percent in parentheses.

	Growth and nutritional status	Overall	Boys	Girls	χ^2
HC-based	Undernutrition (< -2 SD Z score)	515 (60.7%)	255 (59.3%)	260 (62.2%)	0.75^{NS}
	Normal (-2 SD to $+2$ SD)	333 (39.3%)	175 (40.7%)	158 (37.8%)	
MUAC-based	Undernutrition (< -2 SD Z score)	299 (35.3%)	148 (34.4%)	151 (36.1%)	0.27^{NS}
	Normal (-2 SD to $+2$ SD)	549 (64.7%)	282 (65.6%)	267 (63.9%)	
Types of nutritional deficiencies	Both HC and MUAC normal	247 (29.1%)	133 (30.9%)	114 (27.3%)	1.39^{NS}
	One type of undernutrition (HC or MUAC)	388 (45.8%)	191 (44.4%)	197 (47.1%)	
	Both types of undernutrition (HC and MUAC)	213 (25.1%)	106 (24.7%)	107 (25.6%)	

Note. NS = not statistically significant at $p < .05$.

The body circumferences and circumferences to height ratio differences observed between healthy and undernourished children are shown in Table 4. Normal or healthy children of both sexes showed higher mean values in height and weight and significant differences (except girls' height) observed. Six types of circumferences showed a higher mean value in healthy children compared to nutritional deficiencies children, with significant differences observed in both boys and girls (p= <0.001). In both boys and girls, all circumference to height ratio shows statistically significant differences from normal to undernourished children (except head circumference to height ratio in boys).

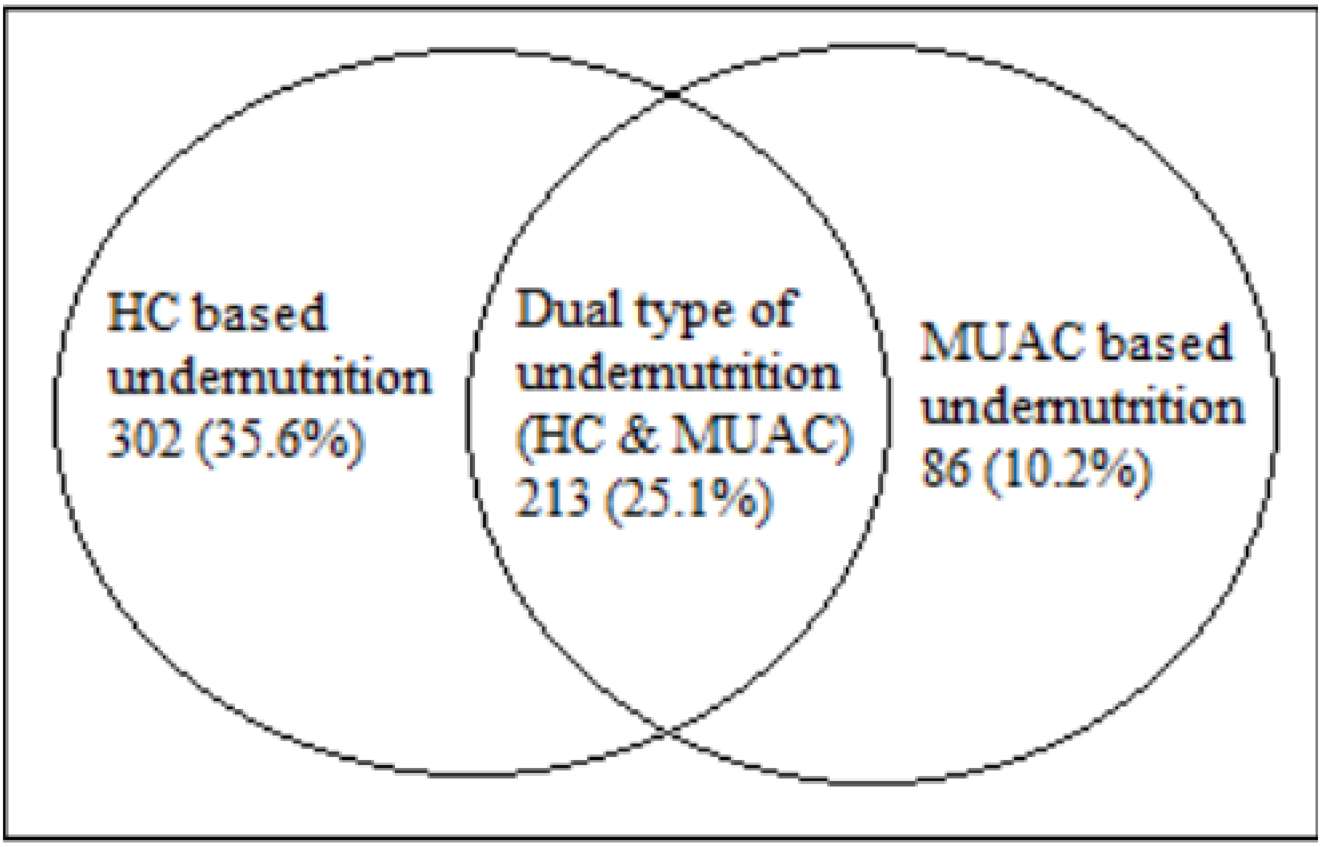

Figure 1. Mid upper arm circumference and head circumference-based growth and nutritional status among the studied tribal preschool children

Table 4: Nutritional status and sex-wise circumference differences among the studied preschool children.

Anthropometric textbfvariables	**Sex**	**Normal** (B = 133; G = 114)	**One type of undernutrition**[a] (B = 191; G = 197)	**Dual type of undernutrition**[b] (B = 106; G = 107)	**F test**
Height					
	Boys	94.36 ± 11.38	88.60 ± 11.72	87.62 ± 11.37	13.13***
	Girls	89.47 ± 12.55	89.40 ± 11.66	89.66 ± 10.41	0.02[NS]
Weight					
	Boys	13.28 ± 2.88	11.41 ± 2.84	10.53 ± 2.55	31.61***
	Girls	12.01 ± 3.24	11.37 ± 2.90	10.60 ± 2.29	6.71***
Head circumference (HC)					
	Boys	47.84 ± 1.45	45.65 ± 1.97	44.67 ± 2.09	95.55***
	Girls	46.34 ± 1.75	44.91 ± 2.03	44.47 ± 1.61	32.07***
Neck circumference (NC)					
	Boys	22.21 ± 1.15	21.71 ± 1.18	20.99 ± 1.05	33.44***
	Girls	21.79 ± 1.32	21.27 ± 1.15	20.78 ± 1.05	20.44***
Mid upper arm circumference (MUAC)					
	Boys	14.07 ± 0.77	13.46 ± 0.85	12.49 ± 0.60	125.70***

Table 4 (continued)

Anthropometric variables	**Sex**	**Normal** (B = 133; G = 114)	**One type of undernutrition**[a] (B = 191; G = 197)	**Dual type of undernutrition**[b] (B = 106; G = 107)	**F test**
	Girls	13.69 ± 0.99	13.31 ± 0.92	12.42 ± 0.69	60.35^{***}
Chest circumference (CC)					
	Boys	48.39 ± 3.11	46.58 ± 3.18	45.11 ± 2.97	33.50^{***}
	Girls	46.67 ± 3.63	46.08 ± 2.93	44.70 ± 2.82	11.76^{***}
Thigh circumference (TC)					
	Boys	23.78 ± 1.99	22.89 ± 2.11	21.80 ± 1.87	28.47^{***}
	Girls	23.88 ± 2.61	23.58 ± 2.60	22.55 ± 2.44	8.36^{***}
Medial calf circumference (MCC)					
	Boys	18.05 ± 1.52	17.24 ± 1.52	16.43 ± 1.39	34.93^{***}
	Girls	17.90 ± 1.73	17.46 ± 1.74	16.81 ± 1.60	11.50^{***}
Head to height ratio (HHtR)					
	Boys	.5132 ± 0.05	.5222 ± 0.06	.5163 ± 0.05	1.17^{NS}
	Girls	.5258 ± 0.06	.5090 ± 0.05	.5011 ± 0.05	6.45^{**}
Neck to height ratio (NHtR)					
	Boys	.2380 ± 0.02	.2484 ± 0.03	.2426 ± 0.02	6.23^{**}
	Girls	.2472 ± 0.03	.2409 ± 0.03	.2341 ± 0.02	6.96^{***}
MUAC to height ratio (AHtR)					
	Boys	.1509 ± 0.02	.1539 ± 0.02	.1443 ± 0.01	11.58^{***}
	Girls	.1549 ± 0.02	.1506 ± 0.01	.1397 ± 0.01	34.14^{***}
Chest to height ratio (CHtR)					
	Boys	.5175 ± 0.05	.5314 ± 0.05	.5202 ± 0.05	3.99^{*}
	Girls	.5275 ± 0.05	.5207 ± 0.04	.5026 ± 0.04	9.15^{***}
Thigh to height ratio (THtR)					
	Boys	.2544 ± 0.03	.2612 ± 0.03	.2516 ± 0.03	4.56^{*}
	Girls	.2691 ± 0.03	.2653 ± 0.02	.2524 ± 0.02	17.59^{***}
Medial calf to height ratio (MCHtR)					
	Boys	.1927 ± 0.02	.1964 ± 0.02	.1893 ± 0.02	5.47^{**}
	Girls	.2017 ± 0.02	.1965 ± 0.01	.1883 ± 0.01	24.25^{***}

Notes. [a]One type of undernutrition indicates either HC- or MUAC-based undernutrition only. [b]Dual type indicates both HC- and MUAC-based undernutrition. NS = not statistically significant $p < .05$. $*\ p < .05$, $**\ p < .01$, $***\ p < .001$.

[a]One type of undernutrition = Children suffered nutritional deficiencies either MUAC based or HC based; [b]Dual type of undernutrition = Children suffered in both MUAC and HC based nutritional deficiencies.

Tables 5 and 6 and the ROC curve (Figure 2) identify the most effective circumferences for predicting dual types of undernutrition. Boys aged 24-35 months have the highest AUC value (0.964), whereas girls aged 48-59 months have the highest AUC value (0.955) of MUAC. The analysis of twelve parameters indicated that, MUAC is the best predictor for the risk of dual types of child undernutrition in boys and girls. In the 12-23-month age group, girls show a higher AUC value in all parameters (except NHtR). In the 24-35-month-old age group, the AUC value fluctuated from parameter to parameter. In the 36–47-month age group, boys show a higher AUC value in all parameters (except thigh circumference, AHtR, and THtR). In the 48–59-month age group, girls show a higher AUC value in all parameters (except head circumference, HHtR). In the 60–71-month age group, boys show a higher AUC value in all parameters (except HHtR, NHtR, and MCHtR).

Table 5: ROC analysis by age group for predicting dual undernutrition among girls.

Variables	Age (M)	AUC	Sig	95% CI	Gini index	Cutoff	Sens	Spe
Head circumference								
	12–23	.845	.000	.762–.928	.690	42.75	.938	.322
	24–35	.744	.000	.638–.850	.489	44.75	.870	.424
	36–47	.711	.000	.597–.826	.423	45.90	.920	.469
	48–59	.793	.000	.702–.885	.587	46.55	.897	.417
	60–71	.850	.000	.753–.947	.700	46.90	1.00	.393
Neck circumference								
	12–23	.708	.008	.553–.862	.416	19.45	.500	.161
	24–35	.769	.000	.649–.888	.537	20.85	.739	.288
	36–47	.666	.014	.533–.799	.332	21.45	.680	.429
	48–59	.840	.000	.756–.925	.680	21.45	.793	.200
	60–71	.751	.000	.622–.880	.503	22.25	.857	.446
Mid upper arm circumference								
	12–23	.952	.000	.912–.991	.903	11.90	.938	.092
	24–35	.933	.000	.884–.983	.867	12.65	.957	.186
	36–47	.945	.000	.892–.998	.890	13.10	.960	.102
	48–59	.955	.000	.918–.993	.911	13.45	.931	.167
	60–71	.899	.000	.828–.970	.798	13.55	1.00	.196
Chest circumference								
	12–23	.808	.000	.688–.928	.616	41.95	.813	.241
	24–35	.829	.000	.741–.917	.658	44.70	.870	.339
	36–47	.826	.000	.731–.921	.652	45.75	.760	.245
	48–59	.799	.000	.709–.890	.599	48.35	.931	.467
	60–71	.693	.010	.547–.839	.385	49.10	.929	.446
Thigh circumference								
	12–23	.813	.000	.707–.918	.625	20.75	.813	.287
	24–35	.761	.000	.652–.870	.522	21.65	.696	.271
	36–47	.780	.000	.673–.887	.560	23.90	.800	.265
	48–59	.732	.000	.625–.840	.465	24.70	.724	.367
	60–71	.621	.169	.449–.792	.241	24.75	.571	.321
Medial calf circumference								
	12–23	.783	.000	.681–.885	.566	15.35	.813	.368
	24–35	.827	.000	.725–.929	.654	16.45	.783	.186
	36–47	.787	.000	.684–.890	.574	17.25	.760	.245
	48–59	.800	.000	.704–.896	.600	18.65	.793	.333
	60–71	.629	.111	.470–.789	.259	19.65	.929	.661
HHtR								
	12–23	.701	.002	.576–.827	.402	.5956	1.00	.667

Table 5 (continued)

Variables	Age (M)	AUC	Sig	95% CI	Gini index	Cutoff	Sens	Spe
	24–35	.564	.349	.429–.700	.129	.5327	.565	.373
	36–47	.408	.178	.275–.542	−.184	.5218	.880	.837
	48–59	.602	.124	.472–.731	.203	.4543	.345	.133
	60–71	.636	.108	.470–.803	.273	.4522	.714	.429
NHtR								
	12–23	.596	.258	.430–.763	.193	.2512	.313	.069
	24–35	.606	.124	.471–.741	.211	.2583	.783	.576
	36–47	.498	.981	.362–.635	−.003	.2308	.480	.367
	48–59	.677	.002	.563–.791	.354	.2243	.897	.533
	60–71	.603	.301	.408–.799	.207	.2078	.571	.286
AHtR								
	12–23	.853	.000	.770–.937	.707	.1639	.938	.287
	24–35	.869	.000	.778–.961	.738	.1494	.783	.136
	36–47	.797	.000	.690–.903	.593	.1477	.960	.347
	48–59	.870	.000	.794–.945	.739	.1367	.862	.200
	60–71	.776	.001	.612–.939	.551	.1251	.571	.054
CHtR								
	12–23	.713	.001	.586–.839	.425	.5764	.875	.517
	24–35	.705	.002	.576–.835	.410	.5238	.652	.271
	36–47	.632	.065	.492–.773	.264	.4944	.480	.163
	48–59	.683	.004	.559–.807	.366	.4757	.517	.200
	60–71	.536	.712	.346–.725	.071	.4566	.429	.196
THtR								
	12–23	.770	.000	.670–.870	.540	.2861	.938	.448
	24–35	.722	.000	.603–.841	.444	.2721	.913	.542
	36–47	.678	.006	.550–.806	.357	.2608	.680	.327
	48–59	.692	.001	.579–.805	.384	.2618	.931	.533
	60–71	.573	.387	.407–.740	.147	.2488	.786	.482
MCHtR								
	12–23	.763	.000	.657–.868	.525	.2067	.875	.333
	24–35	.759	.000	.634–.884	.518	.1899	.565	.102
	36–47	.674	.007	.549–.800	.349	.1909	.720	.347
	48–59	.769	.000	.665–.873	.538	.1889	.828	.350
	60–71	.559	.495	.390–.727	.117	.1828	.643	.464

Notes. Sig = significance; CI = confidence interval; AUC = area under the curve; Sens = sensitivity; Spe = specificity. HHtR = Head to height ratio; NHtR = Neck to height ratio; AHtR = Mid upper arm circumference to height ratio; CHtR = Chest to height ratio; THtR = Thigh to height ratio; MCHtR = Medial calf to height ratio.

Table 6. Age wise ROC analysis of twelve types of circumferences for predicting dual type of undernutrition (growth faltering and nutritional deficiencies) among the studied girls

Table 6: ROC analysis by age group for predicting dual undernutrition among girls.

Variables	Age (M)	AUC	Sig	95% CI	Gini index	Cutoff	Sens	Spe
Head circumference								
	12–23	.845	.000	.762–.928	.690	42.75	.938	.322
	24–35	.744	.000	.638–.850	.489	44.75	.870	.424
	36–47	.711	.000	.597–.826	.423	45.90	.920	.469
	48–59	.793	.000	.702–.885	.587	46.55	.897	.417
	60–71	.850	.000	.753–.947	.700	46.90	1.00	.393
Neck circumference								
	12–23	.708	.008	.553–.862	.416	19.45	.500	.161
	24–35	.769	.000	.649–.888	.537	20.85	.739	.288
	36–47	.666	.014	.533–.799	.332	21.45	.680	.429
	48–59	.840	.000	.756–.925	.680	21.45	.793	.200
	60–71	.751	.000	.622–.880	.503	22.25	.857	.446
Mid upper arm circumference								
	12–23	.952	.000	.912–.991	.903	11.90	.938	.092
	24–35	.933	.000	.884–.983	.867	12.65	.957	.186
	36–47	.945	.000	.892–.998	.890	13.10	.960	.102
	48–59	.955	.000	.918–.993	.911	13.45	.931	.167
	60–71	.899	.000	.828–.970	.798	13.55	1.00	.196
Chest circumference								
	12–23	.808	.000	.688–.928	.616	41.95	.813	.241
	24–35	.829	.000	.741–.917	.658	44.70	.870	.339
	36–47	.826	.000	.731–.921	.652	45.75	.760	.245
	48–59	.799	.000	.709–.890	.599	48.35	.931	.467
	60–71	.693	.010	.547–.839	.385	49.10	.929	.446
Thigh circumference								
	12–23	.813	.000	.707–.918	.625	20.75	.813	.287
	24–35	.761	.000	.652–.870	.522	21.65	.696	.271
	36–47	.780	.000	.673–.887	.560	23.90	.800	.265
	48–59	.732	.000	.625–.840	.465	24.70	.724	.367
	60–71	.621	.169	.449–.792	.241	24.75	.571	.321
Medial calf circumference								
	12–23	.783	.000	.681–.885	.566	15.35	.813	.368
	24–35	.827	.000	.725–.929	.654	16.45	.783	.186
	36–47	.787	.000	.684–.890	.574	17.25	.760	.245
	48–59	.800	.000	.704–.896	.600	18.65	.793	.333
	60–71	.629	.111	.470–.789	.259	19.65	.929	.661
HHtR								

Table 6 (continued)

Variables	Age (M)	AUC	Sig	95% CI	Gini index	Cutoff	Sens	Spe
	12–23	.701	.002	.576–.827	.402	.5956	1.00	.667
	24–35	.564	.349	.429–.700	.129	.5327	.565	.373
	36–47	.408	.178	.275–.542	−.184	.5218	.880	.837
	48–59	.602	.124	.472–.731	.203	.4543	.345	.133
	60–71	.636	.108	.470–.803	.273	.4522	.714	.429
NHtR								
	12–23	.596	.258	.430–.763	.193	.2512	.313	.069
	24–35	.606	.124	.471–.741	.211	.2583	.783	.576
	36–47	.498	.981	.362–.635	−.003	.2308	.480	.367
	48–59	.677	.002	.563–.791	.354	.2243	.897	.533
	60–71	.603	.301	.408–.799	.207	.2078	.571	.286
AHtR								
	12–23	.853	.000	.770–.937	.707	.1639	.938	.287
	24–35	.869	.000	.778–.961	.738	.1494	.783	.136
	36–47	.797	.000	.690–.903	.593	.1477	.960	.347
	48–59	.870	.000	.794–.945	.739	.1367	.862	.200
	60–71	.776	.001	.612–.939	.551	.1251	.571	.054
CHtR								
	12–23	.713	.001	.586–.839	.425	.5764	.875	.517
	24–35	.705	.002	.576–.835	.410	.5238	.652	.271
	36–47	.632	.065	.492–.773	.264	.4944	.480	.163
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	36–47	.674	.007	.549–.800	.349	.1909	.720	.347
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	60–71	.559	.495	.390–.727	.117	.1828	.643	.464

Notes. Sig = significance; CI = confidence interval; AUC = area under the curve; Sens = sensitivity; Spe = specificity. HHtR = Head to height ratio; NHtR = Neck to height ratio; AHtR = Mid upper arm circumference to height ratio; CHtR = Chest to height ratio; THtR = Thigh to height ratio; MCHtR = Medial calf to height ratio.

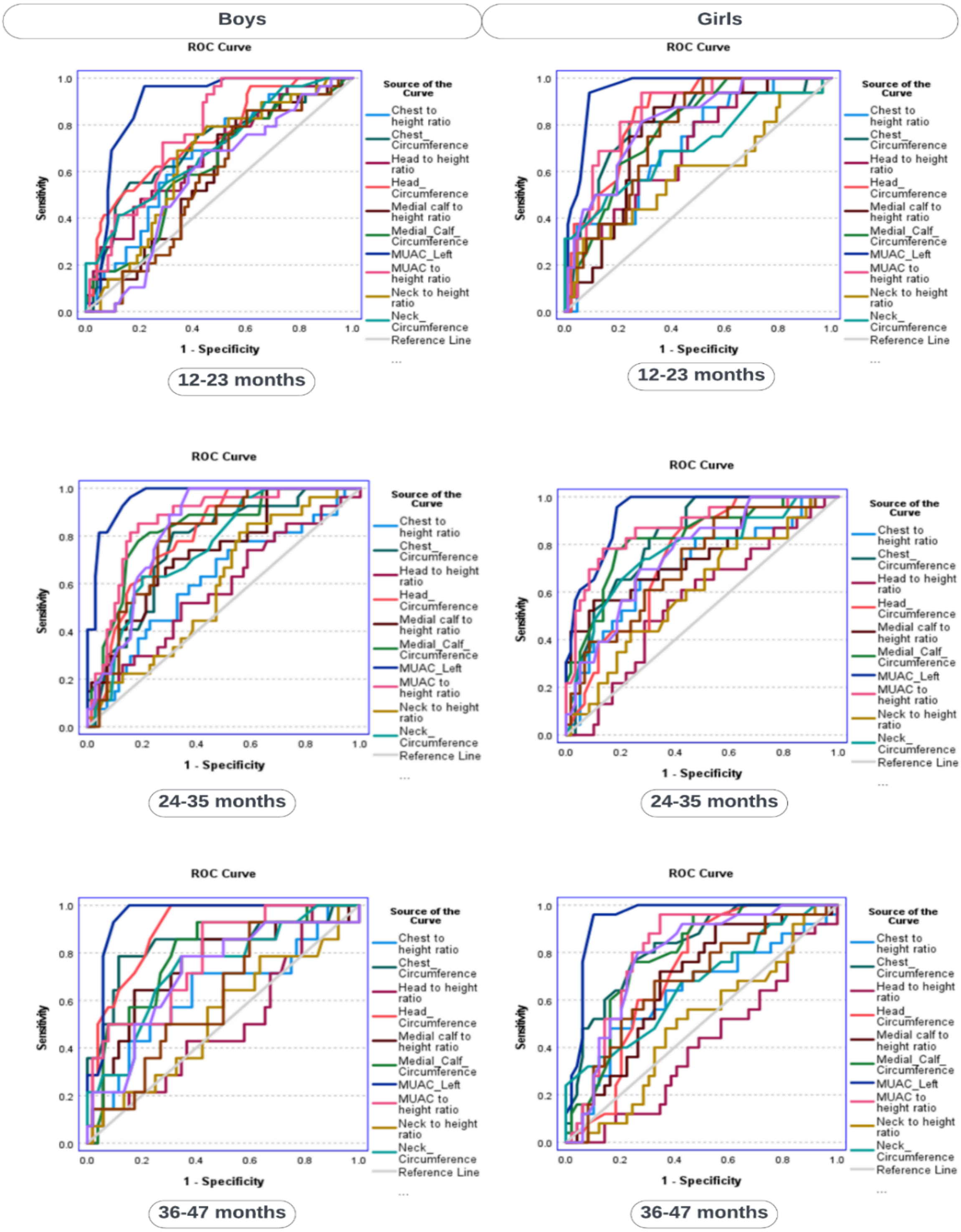

Figure 2a. Age and sex wise ROC curve by using twelve types of parameters for predicting growth faltering and nutritional deficiencies (Part 1)

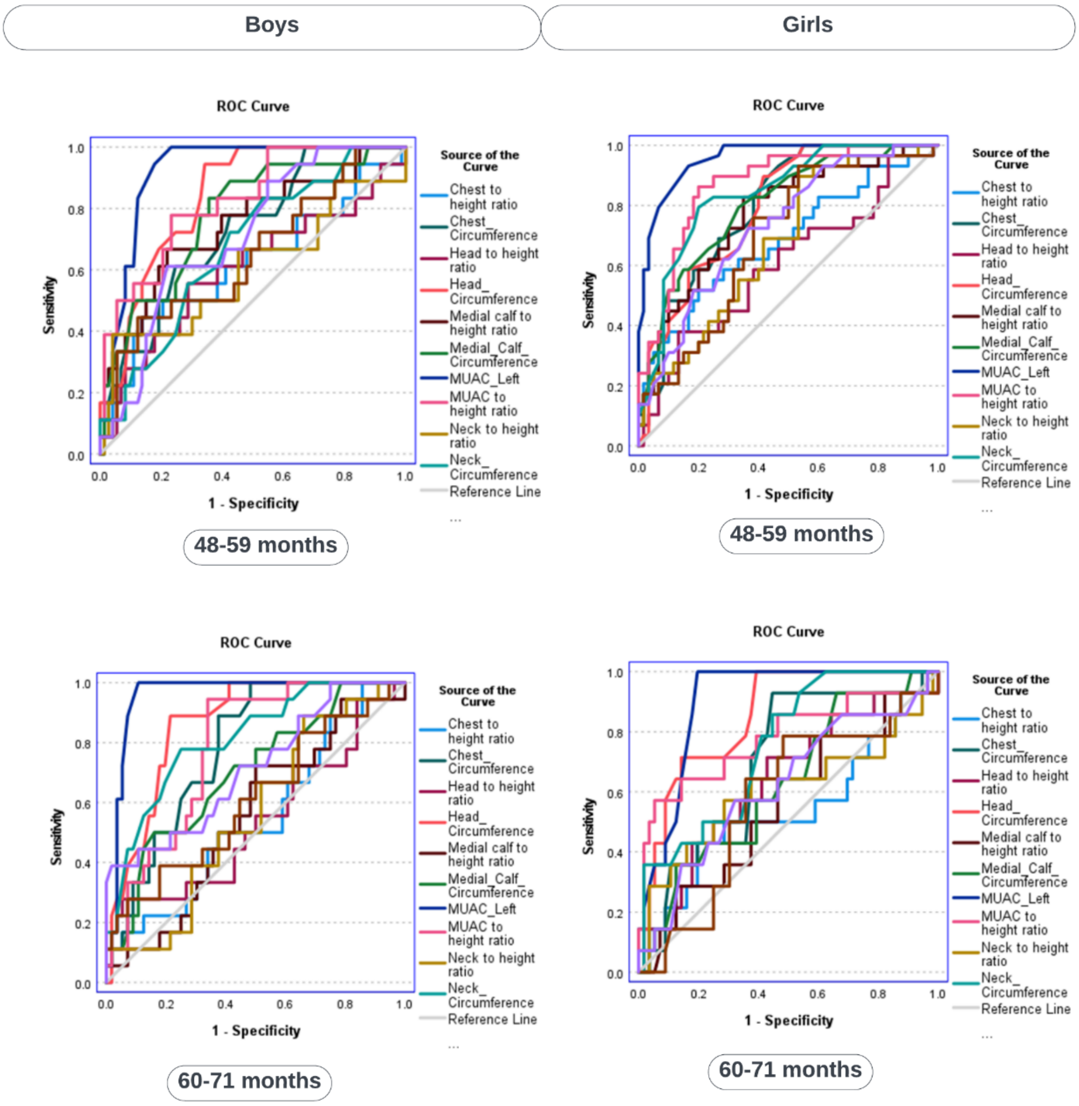

Figure 2b. Age and sex wise ROC curve by using twelve types of parameters for predicting growth faltering and nutritional deficiencies (Part 2)

Undernutrition is a significant global issue, causing 3.1 million child deaths annually, 45% of them in children under five years of age (UNICEF, 2018). A previous study reported that chronic undernutrition in children causes slower cognitive development, major health problems later in life, and reduced life expectancy (Scrimshaw, 1997). The current study found that boys have higher age-adjusted mean body circumferences than girls, with the exception of thigh circumferences. Differences between the sexes were statistically significant, except for medial calf circumferences. Similarly, a previous study in Midnapore town reported that boys had higher mean HC values than girls (Maiti et al., 2012). Many previous studies reported similar findings (Mandal & Bose, 2010; Mondal, 2019).

The present study observed that all body circumferences increased with increasing child age, but the circumference to height ratios decreased with increasing age. Earlier studies had observed that HC increases with age in both sexes (Maiti et al., 2012; Mondal, 2019), and the MUAC value also increases with age (Biswas et al., 2010).

The present study shows that growth and nutritional deficiencies are very common among the studied tribal children, with 70.9% being undernourished; this includes 45.8% who have one type of undernutrition (MUAC or HC) and 25.1% who are undernourished by both measures. Furthermore, the present study indicates that only HC-based undernutrition is 35.6%, only MUAC-based undernutrition is 10.2%, and 25.1% of children suffer from both (Figure 1). Girls experienced marginally higher prevalence of growth and nutritional deficiencies than boys on both measures, but the differences were not statistically significant. Also some previous studies had indicated that girls experience slightly higher rates of undernutrition than boys, as per HC (Maiti et al., 2012; Mandal & Bose, 2010; Mondal, 2019; Tigga et al., 2016) and MUAC (Biswas et al., 2010). Girls in many tribal and rural communities tend to experience slightly higher undernutrition than boys due to a combination of biological, social, and cultural factors. Biologically, girls may have different growth and fat distribution patterns that make deficiencies more visible through indicators like MUAC and HC. Socially and culturally, gender bias in intra-household food distribution, preferential care for boys, and lower healthcare-seeking behaviour for girls often result in poorer dietary intake and delayed treatment of illness.

Normal or healthy children of both sexes show higher mean values in height, weight, and six types of body circumferences than undernourished children, with statistically significant differences observed (except girls' height). In both boys and girls, all circumference to height ratio shows statistically significant differences between normal and undernourished children (except head circumference to height ratio in boys).

Compared to twelve parameters, the present study concludes that MUAC is the best indicator for the risk of growth and nutritional deficiencies in boys and girls. A previous study reported that MUAC is a valuable tool for screening and estimating undernutrition prevalence in preschool children, with a sensitivity and specificity (Joseph et al., 2002) making it a good predictor of child mortality compared to weight for height (Briend & Zimicki, 1986). MUAC has been proposed as the most effective, simple, cost-effective, and acceptable anthropometric parameter for evaluating childhood malnutrition (Myatt et al., 2006). The previous study reveals that MUAC $<$ 11.5 cm or WHZ $<$ -3 is crucial in identifying under-five children at risk of mortality (Sachdeva et al., 2016). Early detection of childhood malnutrition not only improves overall health outcomes, but also minimizes future financial burden (Klanjsek et al., 2019).

4 Limitations

The present study, had some limitations, due to its cross-sectional nature and its small sample size in a small geographical region. Therefore, the results cannot be generalized to the entire state or country. The study design was such that it could not reveal any correlation between socioeconomic factors, mortality, morbidity, and undernutrition based on various parameters.

5 Recommendation

The present study found that undernutrition is a major issue among tribal children and a barrier to their growth and brain development. In India, two main government schemes, the Integrated Child Development Services (ICDS) and POSHAN Abhiyaan, are currently operating to provide supplementary food for preschool children. So, there is an urgent need for strengthening existing nutrition schemes, a requirement for regular monitoring of growth indicators, a quality assessment of food distribution, and timely interventions to address gaps. Ensuring community participation, capacity building of Anganwadi workers, and introducing digital tools for real-time monitoring can improve accountability and efficiency. Also needed are programs to raise parents' awareness of their child's growth and development, nutritional requirements and health. This study also provides cut-off values which can be used in future studies of tribal children.

6 Conclusion

The present study indicates that head circumference (HC)-based nutritional deficiencies are more prevalent than mid-upper arm circumference (MUAC)-based nutritional deficiencies among tribal preschool children. While low MUAC reflects a high prevalence of undernutrition, low HC indicates inadequate brain growth and development, thereby underscoring the multifaceted impact of malnutrition. The use of circumference-to-height ratios further provides critical insights into the proportional growth and development of children. By comparing twelve anthropometric parameters, MUAC emerged as the most reliable predictor of dual forms of child undernutrition across both sexes. It will aid in the early detection of undernutrition among tribal preschool children.

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Ethical approval: The institutional ethical review board of Vidyasagar University's Department of Anthropology provided formal ethical approval. Verbal informed consent was obtained from all participants prior to data collection.

Author contributions: BM collected the data, analysed the data, prepared the first draft of the manuscript, and formatted the manuscript for submission as well. KB supervised the study and reviewed the manuscript.

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