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Original Article

Assessment by neo-CIAF formula predicts contrast occurrence of overweight and undernourishment in preschool children of Jangalmahal districts, India

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ABSTRACT

Objective: Overweight/obesity among preschool children has become an alarming phenomenon in low to middle-income countries, including India. This cross-sectional study aimed to assess the prevalence of overweight and underweight among children aged 2-6 years in Paschim Medinipur and Bankura districts, West Bengal, India.

Methods: We selected 497 children using systematic random sampling. The weight and height of each child was measured. BMI and Z-scores (WAZ, HAZ, WHZ) were calculated following standard techniques. Stunting, wasting, underweight, and composite index of anthropometric failure (CIAF) were evaluated. Data analysis included Student's t-test and one-way ANOVA. Bibliometric analysis was conducted to evaluate the trends of research in this field.

Results: Height and weight increased with age, indicating growth, but BMI declined slightly in older age groups. WAZ scores indicated prevalent underweight across all ages, with significant stunting observed in children aged 48-59 months. WHZ scores showed consistent negative values, suggesting ongoing wasting. The CIAF revealed that 50.91% of children experienced anthropometric failure, predominantly stunting and underweight. The study also revealed that 4.63% of the child suffer from overweight. Girls showed slightly higher rates of anthropometric failure than boys.

Conclusion: This study underscores the significant prevalence of the double burden of malnutrition among young children in Paschim Medinipur and Bankura. Effective interventions are urgently needed to address these challenges, including improving food security, enhancing healthcare services, promoting nutritional education, and ensuring sanitation facilities. Tailored strategies considering local socio-economic contexts are crucial for improving child health outcomes and mitigating the long-term effects of malnutrition in these districts.

Keywords: malnutrition, children, stunting, wasting, CIAF

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INTRODUCTION

The double burden of malnutrition among children remains a critical public health challenge in many developing countries, resulting in both immediate and long-term adverse health effects.[1,2] It negatively impacts children's health and development, increases their vulnerability to illnesses, and significantly raises child morbidity and mortality rates.[3,4] Key measures of a child's nutritional health include indicators such as being underweight, experiencing wasting, and suffering from stunting.[5] Wasting and stunting are particularly significant as they directly indicate undernutrition.[6] Malnutrition, including undernutrition and overnutrition, is a major factor in the global burden of many diseases.[7]

According to the World Bank Report, the under-five mortality rate in India is 34 per 1,000 live births, whereas in West Bengal, it is somewhat lower at 25 per 1,000 live births.[8] Data from the National Family Health Survey (NFHS 5) for 2020-2021 show that in India, 35.5% of children suffer from stunting, 32.1% are underweight, and 19.3% experience wasting. In comparison, the figures for West Bengal are slightly different, with 33.8% of children stunted, 32.2% underweight, and 20.3% wasted.[9]

The prevalence of malnutrition in specific regions of West Bengal, such as Paschim Medinipur and Bankura, underscores the importance of localized studies to identify and address the unique challenges these communities face. These districts, characterized by their diverse socioeconomic conditions and cultural practices, exhibit varying nutritional outcomes among children.[10] For instance, factors such as food insecurity, limited access to healthcare services, inadequate maternal education, and poor sanitation significantly contribute to malnutrition in these areas.[11]

The regions encompassing Bankura, Purulia, Paschim Medinipur, and Jhargram districts in West Bengal are traditionally known by the colloquial term 'Jungle Mahal'. Paschim Medinipur, with its predominantly rural population, often struggles with issues related to agricultural dependency and seasonal variations in food availability, which directly affect children's nutritional intake.[12] Similarly, Bankura, known for its tribal communities, faces challenges such as poverty, illiteracy, and cultural barriers to accessing health services.[13] These socioeconomic determinants play a crucial role in shaping children's health and nutritional status in these districts.

The implications of malnutrition are far-reaching. Children who are malnourished in early life are more likely to suffer from impaired cognitive and physical development, which can hinder their educational performance and productivity in adulthood.[14] Furthermore, malnutrition can lead to a weakened immune system, making children more susceptible to infectious diseases, thereby exacerbating the cycle of poverty and poor health.[15] Addressing malnutrition in Paschim Medinipur and Bankura requires a multifaceted approach that includes improving food security, enhancing maternal and child healthcare services, promoting nutritional education, and ensuring clean water and sanitation facilities.[16] Targeted interventions that consider the local socioeconomic and cultural contexts are essential for effectively combating malnutrition and improving the health outcomes of children in these districts. There is limited data concerning the health profiles and nutritional statuses of preschool children in Paschim Medinipur and Bankura districts. This study aims to assess levels of undernutrition, stunting, wasting, and overweight among preschoolers in these districts of West Bengal, India.

MATERIALS & METHODS

Study location and human participants

A community-based cross-sectional study was conducted from February 2024 to April 2024 among preschool children between the ages of 2 and 6 who resided in Paschim Medinipur and Bankura districts.

Minimal sample size calculation

The minimal estimated sample size was calculated using the standard formula[17]: $n=(z^2pq)/d^2$. The calculation $\{(1.96^2 \times 0.388 \times 0.662)/\ (0.05^2)\}$ was based on 33.8 % of prevalence (P) of stunting at the age of under five years children according to the recent report of the fifth National Family Health Study (NFHS-5) conducted during 2019-2021 in India (NFHS-5)[9], where z=1.96, q=p-1 and the desired precision (d) was ±5. Thus, the estimated sample size was 344 with a dropout rate of 10% was 378. The study focused on children aged between 2 and 6 years. Researchers conducted several visits to the study area within a specific period. Using a systematic random sampling method outlined by Das and Das[18], we selected a sample of 497 children, comprising 263 boys and 234 girls.

Ethical issues

The study was approved by the Institutional Ethics Committee/ Institutional Review Board. Written informed consent was obtained from the respective mothers of the children before the study was conducted.

Anthropometric measurements

Each child's name, age, and sex were recorded, and birth certificates were used to verify their birth dates for data accuracy. Height and weight measurements were taken using standard techniques, accurate to the nearest 0.1 cm and 0.5 kg, respectively.[19] Instruments were properly calibrated before use. Body Mass Index (BMI) was calculated using Quetelet's Index. The nutritional status was evaluated using age- and sex-specific height and weight data from the National Centre for Health Statistics (NCHS) reference.[20] Researchers assessed indices of undernutrition, such as stunting, underweight, and wasting, by calculating Z-scores from height-for-age, weight-for-age, and weight-for-height reference values. The formula for Z-score calculation was applied such as:

$$Z\ Score = \frac{X - Median\ of\ NCHS}{Standard\ Deviation\ of\ NCHS}$$

Where X represents an individual measurement. Z-scores for height-for-age (HAZ), weight-for-age (WAZ), weight-for-height (WHZ), and BMI-for-age (BAZ) were computed. Undernutrition was defined as a Z-score below -2 for any index. The WAZ>+1 was considered as overweight. The composite index of anthropometric failure (CIAF) was calculated using the recently developed equation given by Mahapatra and Bose.[21]

Statistical analysis

Statistical analyses were carried out using the IBM SPSS statistics 25 (2017, IBM Corporation, USA) for Windows. The anthropometric data was analyzed using a software package based on the NCHS database provided by ENA. Continuous variables were analyzed using Student's t-test or one-way analysis of variance (ANOVA) while applicable. If the F value was significant ($p < 0.05$), Dunnet's post hoc test was performed to determine the differences between the pairs of means. Statistical results were considered to be significant at $p < 0.05$.

RESULTS

Demographic and anthropometric profile

Figure 1 analyzes the demographic and anthropometric parameters of 497 children separated by sex (boys and girls). The circular plot (Figure 1a) represents the distribution of age in months. The radial lines appear to correspond to data points, and the numbers around the plot (0/6.28, 1.57, 3.14, 4.71) represent angles in radians. This format indicates the spread of ages across the sample, with the densest data points around the ages of 1.57 and 4.71 radians (approximately 15 months and 45 months, respectively). The scatter plot (Figure 1b) shows the relationship between weight and age. The data points for boys (blue) and girls (orange) show that weight increases with age. The trend lines for boys and girls indicate a similar pattern of weight gain over time, with slight differences between the sexes. Boys tend to have a slightly higher weight trajectory than girls. The violin plots at the top and sideshow that the weight distribution is slightly broader for boys, with most children falling within a weight range of approximately 10 to 20 kg between the ages of 30 and 70 months.

Figure 1c shows that height increases with age, with boys generally being taller than girls at most ages. The violin plots suggest that the height distribution is more varied, especially for boys, with most children falling within the height range of 80 to 120 cm between 30 and 70 months of age. Histogram of BMI (Figure 1d) indicates the mean BMI is 14.86±2.063 kg/m^2. The distribution is roughly normal, as indicated by the overlaid black curve. Most children have a BMI between 13 and 17 kg/m^2, with a few outliers at lower and higher values.

Influence of demographic profile on anthropometric indices

Table 1 explains the impact of the age of the children on the anthropometric parameters. Height measurements showed a significant increase with age, ranging from 86.19 cm (24-35 months) to 105.58 cm (60-71 months) (F=130.588, P<0.001). Weight also increased significantly across age groups, from 11.58 kg (24-35 months) to 16.10 kg (60-71 months) (F=57.273, P<0.001). BAZ declined slightly from -0.20 (24-35 months) to -0.82 (60-71 months) (F=2.926, P<0.05).

WAZ scores ranged from -1.22 to -1.53 across age groups, indicating the tendency towards underweight, but differences were not statistically significant (F=1.142, P>0.05). HAZ scores showed significant variation (F=4.482, P<0.01), with the lowest average (-1.70) observed in children aged 48-59 months, indicating the tendency towards stunting. WHZ scores did not vary significantly with age (F=0.535, P>0.05), hovering around -0.68 to -0.87, indicating consistent levels of wasting. The BAZ shows a significant decline (F = 2.926, P < 0.05) with increasing age, with mean values of -0.20 ± 1.42, -0.59 ± 1.80, -0.51 ± 1.67 and -0.82 ± 1.43 for the age groups 24–35 months, 36–47 months, 48–59 months, and 60–71 months, respectively. The Dunnett post hoc analysis indicated that the youngest age group (24–35 months) had significantly higher BAZ values while comparing among the age groups.

The distribution of z-scores for weight-for-height, height-for-age, and weight-for-age for the preschool children compared with the international reference values is presented in Figure 2. This figure

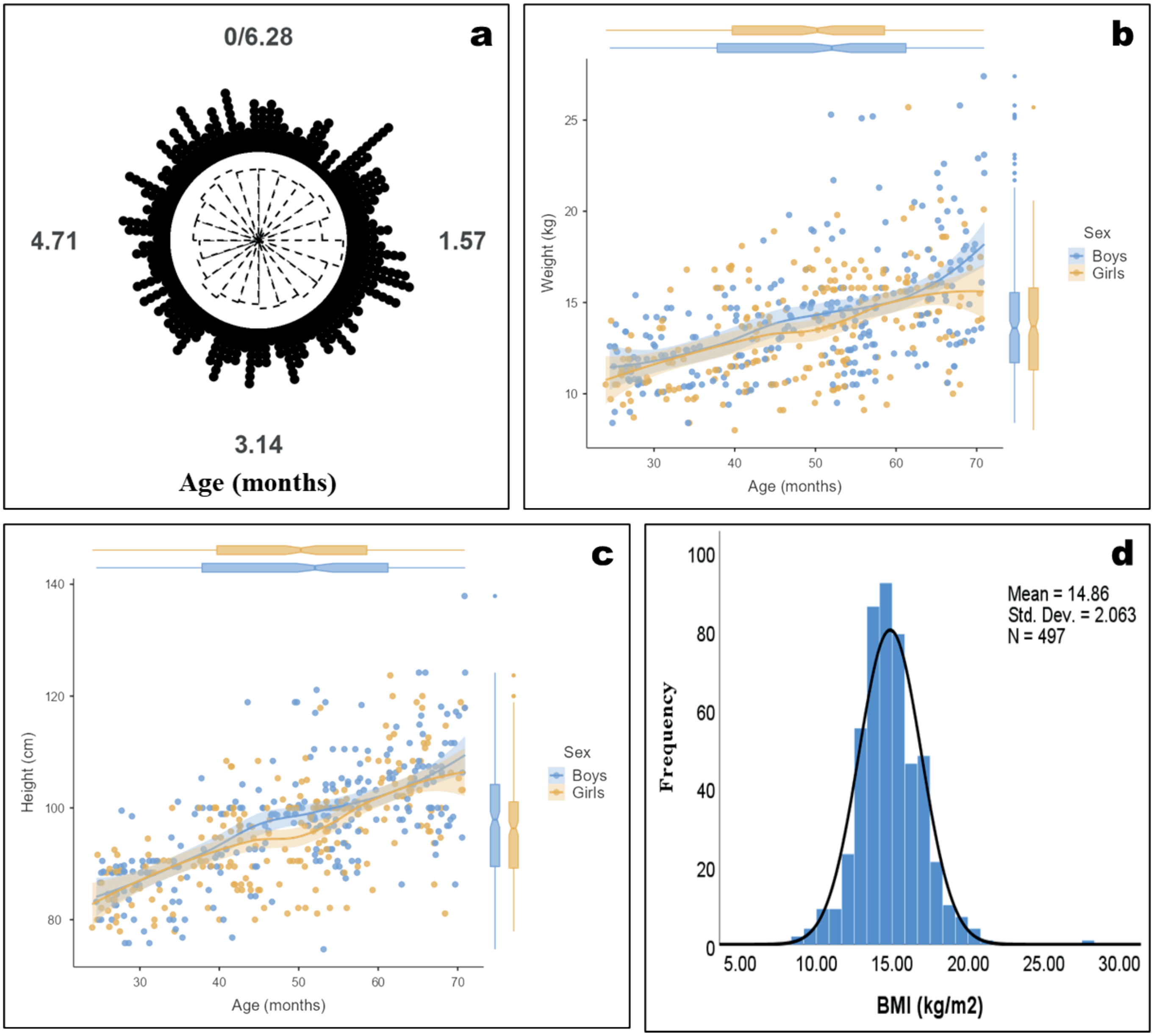

Figure 1. Distribution of the demographic and anthropometric parameters of the children

BMI-Body Mass Index

indicates the negative tendency of WAZ (Figure 2a), HAZ (Figure 2b), and WHZ (Figure 2c), which denotes the undernourishment among the children of Jangalmahal areas. Figure 2d shows the distribution of BAZ for boys and girls. The distributions for both sexes are centered around a z-score of approximately -1 to -2, further highlighting that the children in this study have lower BMI-for-age compared to the reference population. The distribution for boys appears slightly broader, with a notable peak around a z-score of -2.5, while the distribution for girls is narrower, with a peak between -1.5 and -2.0.

Figure 3 presents anthropometric parameters for boys and girls aged 24 to 71 months, including height, weight, BMI, WAZ, HAZ, and WHZ. The results are categorized into four age groups (24-35 months, 36-47 months, 48-59 months, 60-71 months) and a combined age group. For boys, the average height increases with

Table 1. Influence of age (month) of the children on the anthropometric parameters					
Parameters	**24-35 months**	**36-47 months**	**48-59 months**	**60-71 months**	**F**
Height	86.19±5.34	94.05±7.48‡	98.25±7.76‡	105.58±8.82‡	**130.588****
Weight	11.58±1.66	13.12±2.41‡	14.31±2.91‡	16.10±3.29‡	**57.273****
BAZ	-0.20±1.42‡	-0.59±1.80	-0.51±1.67	-0.82±1.43	**2.926***
WAZ	-1.22±1.19	-1.36±1.38	-1.53±1.47	-1.43±1.41	1.142
HAZ	-0.96±1.57	-1.10±1.87	-1.70±1.79‡	-1.39±1.89	**4.482***
WHZ	-0.68±1.06	-0.85±1.42	-0.74±1.44	-0.87±1.22	0.535

P<0.001 (**); P<0.05(*); Post Hoc= P (<0.05) ‡
BAZ: Z-scores for BMI-for-age; WAZ: Z-scores for weight-for-age; HAZ: Z-scores for height-for-age; WHZ: Z-scores for weight-for-height

age: 86.36±5.53 cm for 24-35 months, 94.69±7.91 cm for 36-47 months, 100.02±8.13 cm for 48-59 months, and 105.65±9.11 cm for 60-71 months. The combined age group's average height is 97.29±10.53 cm. The weight shows a similar trend, with means of 11.76±1.58 kg, 13.15±2.24 kg, 14.69±3.21 kg, and 16.40±3.62 kg for the respective age groups, and a combined mean of 14.16±3.33 kg. BMI was relatively decreased with increasing age groups, with values of 15.81±1.94, 14.74±2.27, 14.64±2.42 and 14.58±1.84, resulting in an overall mean of 14.92±2.19. WAZ shows consistent negative values across age groups: -1.24±1.14, -1.46±1.20, -1.50±1.56, and -1.51±1.50, with a combined mean of -1.44±1.39. HAZ decreases slightly over age groups such as -1.05±1.63, -1.11±1.90, -1.46±1.88, and -1.57±1.88, with a combined mean of -1.33±1.39. WHZ values also show negative means: -0.65±1.13, -1.05±1.39, -0.93±1.48, and -0.83±1.28, resulting in a combined mean of -0.86±1.34. For girls, the average height increases from 85.95±5.12 cm for 24-35 months to 105.49±8.52 cm for 60-71 months, with an overall average height of 95.84±9.53 cm. The average weight progresses from 11.31±1.75 kg for 24-35 months to 15.71±2.79 kg for 60-71 months, with an overall average of 13.64±2.86 kg. The BMI values are 15.27±1.44, 14.94±2.17, 14.94±1.99, and 14.09±1.70 for the respective age groups, with a combined mean of 14.81±1.92. WAZ shows negative averages across all groups: -1.20±1.26, -1.28±1.53, -1.57±1.37, and -1.34±1.29, resulting in a combined mean of -1.37±1.37. HAZ values are -0.82±1.48, -1.09±1.87, -1.96±1.65, and -1.17±1.90, with a combined mean of -1.35±1.78. WHZ values for girls are -0.73±0.94, -0.68±1.43, -0.55±1.37, and -0.93±1.15, resulting in a combined mean of -0.70±1.27. Overall, both boys and girls show an increase in height and weight with age. BMI remains relatively stable, while WAZ, HAZ, and WHZ indicate negative trends across all age groups, reflecting potential nutritional or growth challenges.

Nutritional status of the children and its determinants

Table 2 shows the prevalence of underweight, stunting, wasting, and Composite Index of CIAF across different age groups (24-71 months) among boys, girls, and the combined group. Among boys, the prevalence of underweight is highest in the 48-59 months group at 39.02%, with an odds ratio (OR) of 1.656, while for girls, it peaks at 44.07% in the 36-47 months group (OR = 1.818). Stunting is most prevalent in boys aged 60-71 months (37.68%, OR = 1.854) and girls aged 48-59 months (39.74%, OR = 2.886). Wasting is notably higher in girls aged 36-47 months at 23.73% (OR = 4.148) compared to boys in the same age group, who have a prevalence of 21.57% (OR = 1.589). The CIAF, which captures multiple forms of malnutrition, is particularly high in the 36-47 months age group for girls (67.80%, OR = 3.220) and boys (52.94%, OR = 1.514), with the combined prevalence in this age group reaching 60.91% (OR = 2.210). This data highlights the significant burden of undernutrition in these specific age groups, particularly among girls.

Table 3 presents the distribution of the CIAF among boys, girls, and combined sexes in Paschim Medinipur and Bankura districts. The CIAF categorizes children based on anthropometric indicators, including wasting, stunting, underweight, and overweight. Most children in Group A (49.09%) showed no anthropometric failure, with similar proportions between boys (50.95%) and girls (47.01%). Group B, characterized by wasting only, comprised 2.82% of children overall, with a slightly higher prevalence among girls (3.85%) compared with boys (1.90%). Group C included children who were both wasting and underweight (7.65%), with comparable distributions across sexes. Group D, involving wasting, stunting, and underweight, accounted for 6.04% of children, with a higher proportion among boys (7.60%) than girls (4.27%). Group E, characterized

Table 2. Influence of age and sex on the nutritional status of the children

	Boys				Girls				Sex combined			
Age (months)	N	Underweight	χ²	OR [95%CI]	N	Underweight	χ²	OR [95%CI]	N	Underweight	χ²	OR [95%CI]
24-35	61	17 (27.87)®			43	13 (30.23)®			104	30 (28.85)®		
36-47	51	18 (35.29)	0.713	1.412 [0.633-3.148]	59	26 (44.07)	2.016	1.818 [0.793-4.167]	110	44 (40.00)	2.940	1.644 [0.930-2.909]
48-59	82	32 (39.02)	1.933	1.656 [0.811-3.384]	78	29 (37.18)	0.590	1.366 [0.616-3.029]	160	61 (38.13)	2.402	1.520 [0.894-2.584]
60-71	69	26 (37.68)	1.408	1.565 [0.745-3.286]	54	13 (24.07)	0.463	0.732 [0.297-1.802]	123	39 (31.71)	0.218	1.145 [0.648-2.024]
		Stunting				**Stunting**				**Stunting**		
24-35	61	15 (24.59)®			43	8 (18.60)®			104	23 (22.12)®		
36-47	51	13 (25.49)	0.012	1.049 [0.445-2.475]	59	19 (32.20)	2.363	2.078 [0.810-5.333]	110	32 (29.09)	1.362	1.445 [0.778-2.684]
48-59	82	29 (35.37)	1.907	1.678 [0.802-3.510]	78	31 (39.74)	5.671*	2.886 [1.183-7.041]	160	60 (37.50)	6.921**	2.113 [1.203-3.710]
60-71	69	26 (37.68)	2.570	1.854 [0.868-3.963]	54	16 (29.63)	1.563	1.842 [0.702-4.835]	123	42 (34.15)	3.992*	1.826 [1.008-3.309]
		Wasting				**Wasting**				**Wasting**		
24-35	61	9 (14.75)®			43	3 (6.98)®			104	12 (11.54)®		
36-47	51	11 (21.57)	0.879	1.589 [0.601-4.202]	59	14 (23.73)	5.026*	4.148 [1.111-15.492]	110	25 (22.73)	4.680*	2.255 [1.066-4.768]
48-59	82	14 (17.07)	0.139	1.190 [0.478-2.961]	78	11 (14.10)	1.376	2.189 [0.576-8.321]	160	25 (15.63)	0.873	1.420 [0.679-2.968]
60-71	69	10 (14.49)	0.002	0.979 [0.370-2.595]	54	10 (18.52)	2.748	3.030 [0.778-11.800]	123	20 (16.26)	1.037	1.489 [0.690-3.212]
		CIAF				**CIAF**				**CIAF**		
24-35	61	26 (42.62)®			43	17 (39.53)®			104	43 (41.35)®		
36-47	51	27 (52.94)	1.186	1.514 [0.717-3.200]	59	40 (67.80)	8.058**	3.220 [1.419-7.309]	110	67 (60.91)	8.190**	2.210 [1.279-3.819]
48-59	82	45 (54.88)	2.101	1.637 [0.839-3.194]	78	42 (53.85)	2.272	1.784 [0.838-3.801]	160	87 (54.85)	4.281*	1.691 [1.026-2.785]
60-71	69	31 (44.93)	0.070	1.098 [0.548-2.200]	54	25 (46.30)	0.446	1.318 [0.585-2.971]	123	56 (45.53)	0.401	1.186 [0.700-2.009]

Significance level at P<0.001 (**); P<0.05(*). ®: Reference
CIAF: Composite Index of Anthropometric Failure

Table 3. Influence of sex on the composite index of anthropometric failure (CIAF)				
Group	**Categories**	**Boys**	**Girls**	**Sex Combined**
A	No failure	134 (50.95)	110 (47.01)	244 (49.09)
B	Wasting only	5 (1.90)	9 (3.85)	14 (2.82)
C	Wasting and underweight	19 (7.22)	19 (8.12)	38 (7.65)
D	Wasting, stunting and underweight	20 (7.60)	10 (4.27)	30 (6.04)
E	Stunting and underweight	43 (16.35)	42 (17.95)	85 (17.10)
F	Stunting only	20 (7.60)	22 (9.40)	42 (8.45)
G	Stunting and overweight	-	-	-
H	Overweight only	11 (4.18)	12 (5.13)	23 (4.63)
I	Stunting and wasting only	-	-	-
Y	Underweight only	11 (4.18)	10 (4.27)	21 (4.23)
	Total CIAF (B-Y)	129 (49.05)	124 (52.99)	253 (50.91)

Data presented as N (%)
CIAF: Composite Index of Anthropometric Failure

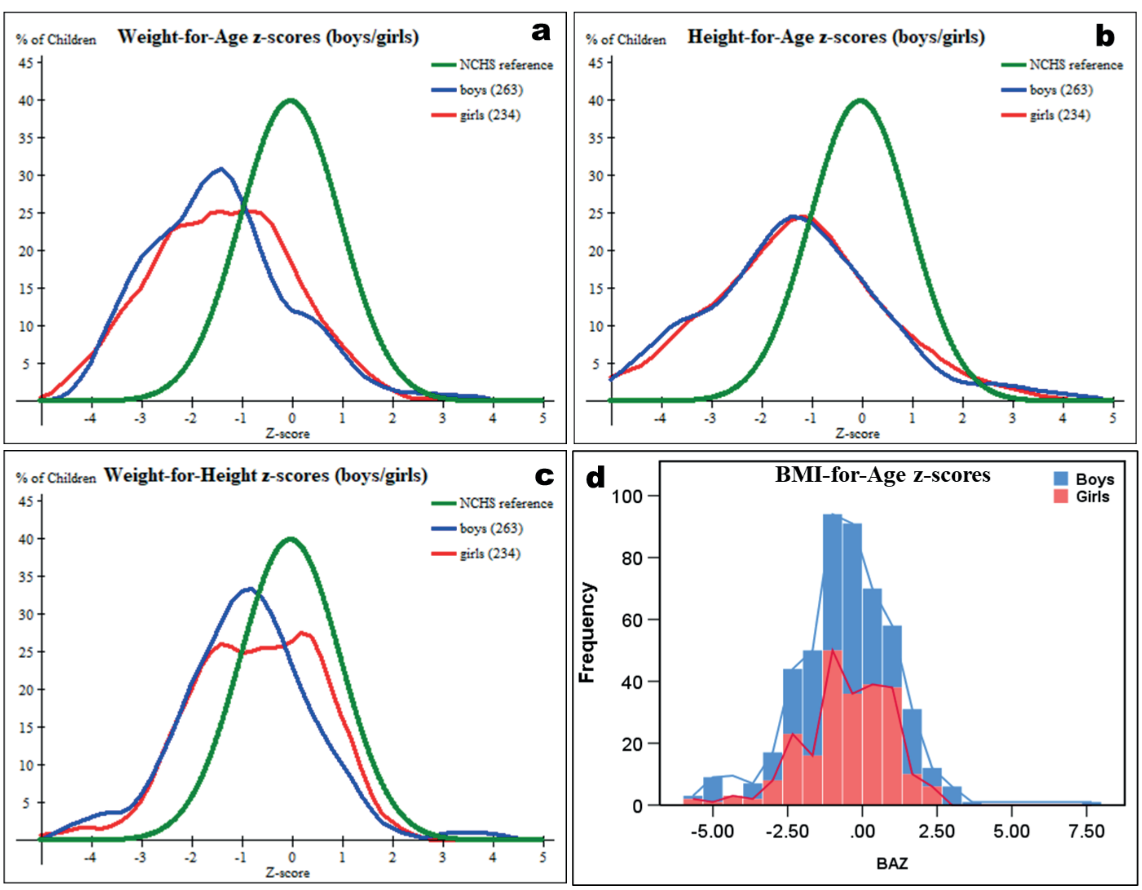

Figure 2. Z-score of the weight for age, height for age, weight for height, and BMI for age among the children

NCHS-National Center for Health Statistics, BAZ-BMI-for-Age z-score by stunting and underweight, represented 17.10% of children, again showing similar distributions between boys (16.35%) and girls (17.95%). Group F, stunting only, comprised 8.45% of children, with a slightly higher prevalence among girls (9.40%) than boys (7.60%). Group H, overweight only, represented 4.63% of children, with a slightly higher prevalence among girls (5.13%) compared with boys (4.18%). Group Y, underweight only, accounted for 4.23% of children, with similar distributions between boys (4.18%) and girls (4.27%). Overall, the combined CIAF (sum of Groups B-Y) indicated that 50.91% of children in the study area experienced some form of anthropometric failure. There was a slight predominance among girls (52.99%) compared to boys (49.05%). These results underscore the multifaceted nature of malnutrition among children in Paschim Medinipur and Bankura districts, with significant proportions experiencing various combinations of wasting, stunting, underweight, and overweight.

DISCUSSION

The findings of this cross-sectional study reveal significant variations in the anthropometric parameters of children aged 2 to 6 years in Jangalmahal areas of West Bengal, highlighting the complex nature of malnutrition in these regions. The results illustrate the impact of age on height, weight, BMI, WAZ, HAZ, WHZ, and BAZ, providing critical insights into the prevalence and distribution of undernutrition among these children. The data showed a clear trend of increasing height and weight with age, reflecting expected growth patterns. This growth trajectory indicates that, on average, children in the study population are experiencing linear growth and weight gain appropriate for their age groups. Such patterns align with established growth standards, suggesting that while overall growth is occurring, underlying issues need to be addressed.[22] Despite the increase in height and weight, the slight decline in BMI as children age suggests that their weight gain is not keeping pace with their height growth. This trend could be indicative of emerging nutritional and health issues, where children may be growing taller but not gaining adequate weight. The persistent negative WAZ scores across all age groups point to a widespread issue of underweight, indicating that undernutrition is a significant concern for these children. Consistent negative WAZ scores across age groups suggest that underweight remains a persistent problem, necessitating targeted nutritional interventions. The variation in HAZ scores, with the lowest values observed in a particular age group, signals a notable incidence of stunting, indicative of chronic malnutrition. Stunting reflects long-term nutritional deficits, which could have lasting impacts on

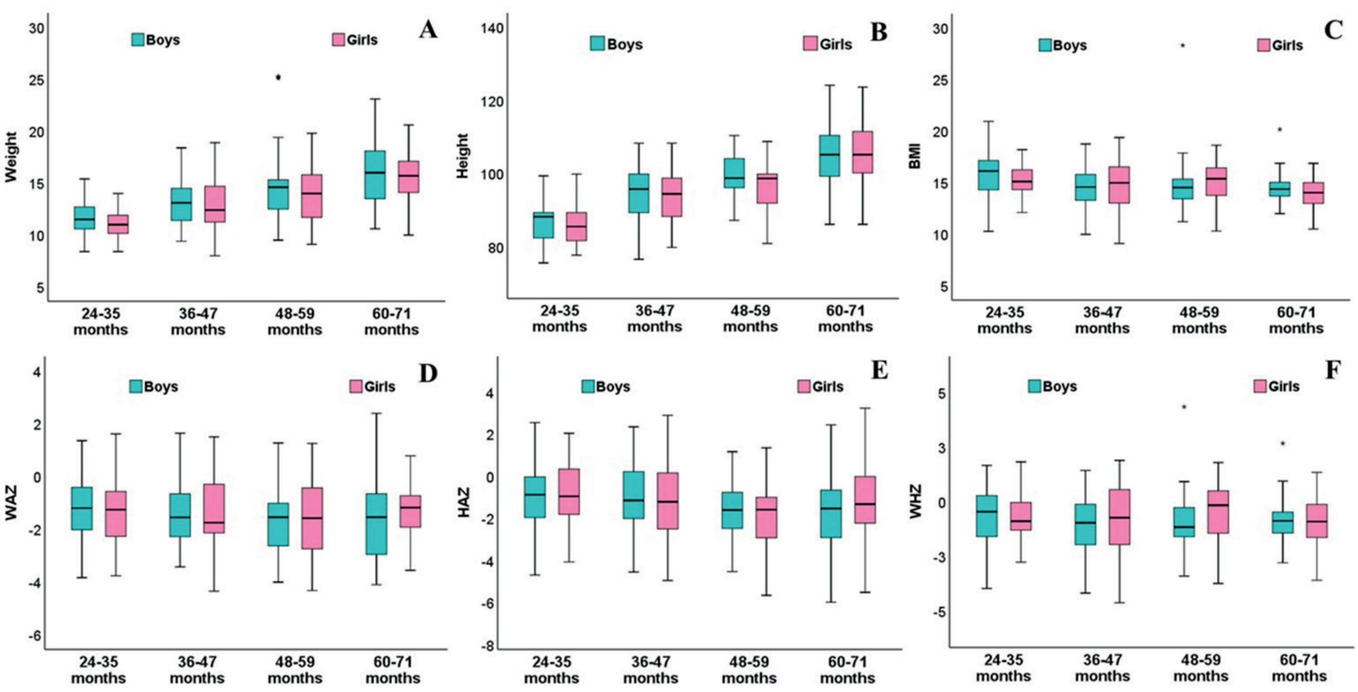

Figure 3. Influence of age and gender on different anthropometric indices

BMI-Body Mass Index; WAZ-Weight-for-Age z-score; HAZ-Height-for-Age z-score; WHZ- Weight-for-Height z-score children's physical and cognitive development. These findings align with other studies that report high stunting prevalence in similar contexts, highlighting the need for sustained nutritional support.[23] Notably, the children were not meeting the typical weight and height benchmarks as defined by the NCHS standards. It was noted that both boys and girls are below the expected weight and height compared to the NCHS reference data (Figure 2). Additionally, the data shows that boys and girls have very similar measurements in terms of height and weight. Similar kinds of results were reported earlier by Sinha et al.[24]

Figure 3 provides an overview of nutritional status indicators among children aged 24-71 months, categorized by gender and age groups. It outlines prevalence rates of underweight, stunting, and wasting across different periods. The findings highlight varying degrees of malnutrition across age and gender categories. For instance, underweight prevalence is highest among boys aged 48-59 months (39.02%) and girls aged 36-47 months (44.07%). Stunting rates are notably high among boys aged 60-71 months (37.68%) and girls aged 48-59 months (39.74%). Wasting rates are relatively lower but show a consistent pattern across age groups and genders. This study also provides a detailed analysis of the relationships between various anthropometric indices in children, highlighting significant trends and correlations that are crucial for understanding childhood growth patterns. Younger children exhibit a wider range of HAZ based on their WHZ, with this variability decreasing as they age, indicating that early nutritional status has a profound impact on linear growth.[25] A strong positive correlation between Weight and Height ($r = 0.79$, $p < 0.001$) and between BMI and both BAZ ($r = 0.97$, $p < 0.001$) and WHZ ($r = 0.92$, $p < 0.001$), underscoring the importance of BMI as a reliable indicator of nutritional status in children.[26] Age also correlates moderately with Weight ($r = 0.51$, $p < 0.01$) and Height ($r = 0.66$, $p < 0.01$), suggesting that as children grow older, their weight and height generally increase, consistent with typical growth trajectories.[26] These insights underscore the necessity of early and continuous nutritional interventions to mitigate the risk of long-term growth impairments and emphasize the value of using multiple anthropometric measures to accurately assess and address malnutrition in pediatric populations.

WHZ scores, which remained consistently negative and did not show significant variation with age, indicate ongoing levels of wasting among the children. Wasting is often a result of acute nutritional deficiencies and underscores the immediate need for nutritional interventions and healthcare support to address this acute form of undernutrition. These results are consistent with global wasting patterns in regions facing nutritional challenges.[27]

It is probably the first study in Paschim Medinipur and Bankura district where we have considered the newly developed formula for evaluating CIAF in which the overweight is also included, along with stunting, wasting, and underweight. The prevalence of stunting, wasting, underweight, overweight, and CIAF among preschool children in this locality was 31.59%, 16.50%, 35.01%, 4.63%, and 50.91%, respectively.

The CIAF analysis revealed that a significant proportion of children experienced some form of anthropometric failure, with a slightly higher prevalence among girls compared to boys. The majority of children showed no anthropometric failure, but a substantial number were affected by various forms of undernutrition. This finding indicates diverse patterns of malnutrition, necessitating comprehensive and multifaceted intervention strategies to address the specific combinations of wasting, stunting, and underweight observed.

In addition to nutritional factors, various socioeconomic elements significantly contribute to malnutrition. Poor hygienic conditions, inadequate sanitation, lifestyle factors, and low levels of education play crucial roles. Infections, cultural practices related to childcare, breastfeeding, weaning, and superstitions also impact the nutritional status of certain communities. The children included in this study were randomly selected from marginalized or underprivileged groups. Previous research on similar populations indicates that many children do not complete their immunization schedules due to parental ignorance and lack of health awareness. Moreover, these children often face poor hygiene, detrimental household practices, infectious diseases, and malnutrition.[24,28]

This study provides robust evidence of the varying impacts of age on anthropometric parameters and underscores the prevalence of malnutrition among young children in Paschim Medinipur and Bankura districts. The significant findings regarding height, weight, BMI, WAZ, HAZ, and WHZ highlight the urgent need for targeted nutritional and health interventions to address the complex nature of undernutrition in these regions. Future research should focus on understanding the underlying causes of these nutritional deficits and developing effective strategies to combat them.

Strengths and limitations of this study

The strength of this work is that it briefly outlines the occurrence of malnutrition in the rural forest-based area in the southern part of West Bengal state. This place is comparatively more eco-restored and environmentally rich territories where migrated populations and industrial/commercial activities are scanty. In this community, children are found to have diverse nutritional status, both malnutrition and overnutrition. This indicates the infiltration of multicultural practices in the community, which may be due to the advancement of information technology, digitization, and tourism-related activities. The attributing factors related to our present findings have not been well-focused in the current study and might be the topic of future research. Other environmental and confounding factors have not been discussed in the current study. Considering that under and over-nutrition develops adverse physiological status and may even create pathological conditions in association with other factors, multidimensional strategies are required for better health interventions in these communities.

CONCLUSION

In conclusion, the study underscores the pervasive issue of malnutrition among children aged 2 to 6 years in Paschim Medinipur and Bankura districts, revealing significant variations in anthropometric parameters such as height, weight, BMI, WAZ, HAZ, WHZ, and BAZ. Probably, it was the first study to evaluate the nutritional status of children using the recently developed CIAF by Mahapatra and Bose, where overweight is also included while calculating CIAF. This also emphasized the double burden of malnutrition. While children generally exhibit expected growth patterns in terms of height and weight, persistent underweight, stunting, and wasting indicate ongoing challenges in nutritional status. These findings necessitate targeted interventions addressing both immediate nutritional deficiencies and underlying socioeconomic factors contributing to malnutrition. Effective strategies should focus on improving health awareness, promoting hygienic practices, and ensuring access to nutritious diets to mitigate the complex impacts of undernutrition on child development and well-being in these regions.

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Ethical approval

This study has been approved by the Institutional Ethics Committee of Raja Narendralal Khan Women's College (Autonomus) [approval date 07.02.2024, number 03/IEC/RNLKWC/2024]. Written informed consent was obtained from the parents/care givers of the participants.

Author contribution

Study Concept: RD, SM, SM, NKS; Design: SM, SM, NKS; Data Collection or Processing: SC, SP, DA, BM; Analysis or Interpretation: SM, NKS; Literature Search: RD, SC, SP; Writing: BM, SM, SM. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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