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SOCIO-ECONOMIC AND DEMOGRAPHIC CORRELATES OF COMPOSITE INDEX OF ANTHROPOMETRIC FAILURE AMONG RURAL CHILDREN IN WEST BENGAL, INDIA

Jaydip Sen[1], Sampriti Debnath[2], Nitish Mondal[3]

Abstract: The composite index of anthropometric failure (CIAF) is a recently proposed alternate anthropometric measure to assess the actual magnitude of undernutrition in children. The present investigation aims to determine the prevalence of undernutrition using CIAF and the effect of several socio-economic and demographic correlates. This cross-sectional investigation was undertaken in 1090 (520 boys; 570 girls) children aged 5-10 years in West Bengal, India. The anthropometric indices of wasting, underweight, stunting and CIAF were calculated by comparing with the international reference data. Chi-square analysis and binary logistic regression (BLR) analysis was done using SPSS (version 17.0). The overall prevalence of wasting, underweight, stunting and CIAF was observed being 15.05%, 35.50%, 29.54% and 48.35%, respectively. Girls were more affected than boys by wasting (17.02% vs. 12.85%). Boys were more affected than girls by underweight (39.04% vs. 32.28%), stunting (29.81% vs. 29.30%) and CIAF (49.62% vs. 47.19%) ($p>0.05$). BLR analysis showed several socio-economic and demographic variables were significantly associated with single, double and multiple anthropometric failures ($p<0.05$). Present investigation will help to identify the actual magnitude of undernutrition among rural Indian children. Identifications of socio-economic and demographic variables will be helpful to formulate appropriate intervention strategies.

Keywords: Anthropometry, Children, CIAF, Public Health, Undernutrition

INTRODUCTION

Undernutrition is one reason of the high child mortality, morbidity and detrimental factor to the future of those who survive (Black et al. 2003; Nandy et al. 2005; Black et al. 2013). The prevalence of undernutrition being the principal cause of death of 45.0% of less than 5 year's old children worldwide (Black et al. 2013; Ramachandran 2014) and the leading cause of death among children in the developing countries (UNICEF 1998; WHO 2001; Debnath et al. 2017). India has been witnessing highest prevalence of global childhood undernutrition (UNICEF 2013). Poverty and poor socio-economic conditions are being the major underlying causes of undernutrition in the country (Antony and Laxmaiah 2008; Ahmed et al. 2012; Varadharajan et al. 2013; Ramachandran 2014; Rengma et al. 2016; Debnath et al. 2018). Cultural practices and gender discrimination are the important contributors to undernourishment among female child. Several researchers have reported that girls are vulnerable than boys (Bose et al. 2007; Mondal and Sen

1. Professor, Department of Anthropology, University of North Bengal, Raja Rammohunpur, District: Darjeeling - 734013, West Bengal, India. E-mail: jaydipsen@rediffmail.com (Corresponding Author); 2. UGC-Senior Research Fellow, Department of Anthropology, University of North Bengal, Raja Rammohunpur, District: Darjeeling - 734013, West Bengal, India; 3. Assistant Professor, Department of Anthropology, Assam University, Diphu Campus, Diphu, Karbi Anglong - 782460, Assam, India.

2010; Sen and Mondal 2012; Bellows et al. 2015; Tigga et al. 2015a,b; Angadi and Jawaregowda 2017; Newman and Newman 2017; Debnath et al. 2018). India with its significant economic development is suffering from overweight and obesity in urban regions and facing challenges due to the persisting public health problem of child undernutrition (>40.0%) in the country (Mondal and Sen 2010; Varadharajan et al. 2013; Ramachandran 2014; Mondal et al. 2015; Debnath et al. 2018).

Anthropometric measures are the non-invasive, inexpensive, reliable, widely used and accepted technique to assess child undernutrition. The most used conventional anthropometric measures to assess undernutrition are stunting (low height-for-age), underweight (low weight-for-age), wasting (low weight-for-height) and thinness [Low Body Mass Index (BMI)-for-age] (WHO 1995, 2007; Nandy et al. 2005; Mondal and Sen 2010; Sen et al. 2012. The conventional anthropometric measures reflect distinct but prominent biological processes. But they cannot reflect the overall magnitude when children experience multiple anthropometric failures or deficits (Svedberg 2000; Nandy et al. 2005; Nandy and Svedberg 2012; Agarwal et al. 2015; Dasgupta et al. 2015). Different types of undernutrition (e.g., stunting or wasting) contributes to different mortality and morbidity risks in children (Pelletier et al. 1995; Asfaw et al. 2015; Liu et al. 2015; Debnath et al. 2017). The Composite Index of Anthropometric Failure (CIAF) is now being adopted by researchers to identify the aggregate level of undernutrition among children. It is more often greater than the values determined by conventional anthropometric measures (i.e., stunting, underweight and wasting) (Nandy et al. 2005; Nandy and Miranda 2008; Sen and Mondal 2012; Nandy and Svedberg 2012; Ziba et al. 2017). Studies have observed that children with multiple anthropometric failures (i.e., CIAF) have greater risks of experiencing serious ailments or morbidity risk (Nandy et al. 2005; Nandy and Svedberg 2012; Fentahun et al. 2016; Ziba et al. 2017).

Several researchers have reported that CIAF is more useful than the conventional anthropometric measures for assessing the magnitude of undernutrition and identifying children with multiple anthropometric failures (Nandy et al. 2005; Nandy and Miranda 2008; Nandy and Svedberg 2012; Sen and Mondal 2012; Khan and Raza 2014; Savanur and Ghugre 2015; Fentahun et al. 2016; Kramsapi et al. 2018). CIAF comprises the conventional anthropometric measures and seven different their combinations for studying undernutrition (Table 1). Several studies have used the proposed classification of CIAF for assessing the overall magnitude of undernourishment among children (Nandy et al. 2005; Seetharaman et al. 2007; Biswas et al. 2009; Das and Bose 2009; Deshmukh et al. 2009; Mandal and Bose 2009; Mukhopadhyay et al. 2009; Sen et al. 2012; Agarwal et al. 2015; Savanur and Ghugre 2015; Dhok and Thakre 2016; Goswami 2016; Gupta et al. 2017; Vollmer et al. 2017; Kramsapi et al. 2018).

Studies have reported significant associations between socio-economic, demographic variables (e.g., family size, birth order, fathers occupation, mothers occupation, monthly household income/per capita income) and CIAF in children (Kumar et al. 2010; Mukhopadhyay and Biswas 2011; Sen and Mondal 2012; Khan and Raza 2014; Dasgupta et al. 2015; Fentahun et al. 2016; Vollmer et al. 2017; Ziba et al. 2017). Children belonging to the poorest household endured the burden of undernutrition more than those from the higher income households (Sen et al. 2012; Pulok et al. 2016; Mondal et al. 2015; Debnath et al. 2018; Kramsapi et al. 2018). Studies have also reported the prevalence of CIAF among children regarding different geographical locations (Nandy and Svedberg 2012; Dasgupta et al. 2015; Boregowda et al. 2015; Daral et al. 2017; Kherde et al. 2018). Anthropometric indices are useful markers to determine actual nutritional failure or deprivation at the country/ regional level. Children living in rural areas are more nutritionally vulnerable than their urban counterparts.

Evaluation of the effects of different socio-economic, demographic and lifestyle factors on CIAF is necessary to identify the nutritional vulnerability of children. Special attention is required in health inequalities during the early years of life as they are likely to perpetuate in future adult population. The importance of the present investigation lies that there is very less number of studies which have used CIAF for assessing undernutrition. Few studies have reported the associations between different categories of anthropometric failures (i.e., single failure, double failure and multiple failures) and socio-economic, demographic and lifestyle variables in population. Therefore, the aims of the present investigation are to assess the prevalence of undernutrition using both conventional anthropometric measures and CIAF and to determine the associations of certain socio-economic and demographic factors on CIAF among rural children. The data of the present investigation will be beneficial to the Government agencies and policy-making bodies to plan an appropriate programme and/or find out the current efficacy of ongoing nutritional intervention programmes.

MATERIALS AND METHODS

Study region, subjects and method of sampling

The present cross-sectional investigation was carried out among 1090 school going children (boys: 520; girls: 570) aged 5-10 years living in Phansidewa Block of the Darjeeling district of West Bengal, India. This block (Latitude 26º 34´59´´ N, Longitude 88º 22´00´´ E) covers an area of 308.65 km^2 is near the Indo-Bangladesh border and ~35–40 km from the sub-divisional town of Siliguri and comprises of 171 508 individuals (males: 87,945; females: 83,563) with the literacy rate of 41.59% (males: 51.85%; females: 30.80%)(Census of India 2011). The children were living at the block of Phansidewa, which have access to all the basic amenities (e.g., hospitals, schools, post office, markets and government offices) (Mondal and Sen 2010; Debnath et al. 2018).

They were the students of 10 primary schools covered under the block. These schools were identified based on student strengths and accessibility by road. Children were selected using a stratified random sampling method. A minimum number of research participants required for estimating the prevalence of undernutrition was estimated following the standard sample size estimation method (Lwanga and Lemeshow 1991). In this method, the expected population proportion of 50%, absolute precision of 3% (<5%; i.e., the lower margin of error) and confidence interval of 95% were taken into consideration. The minimum number of sample size estimated for the present investigation was 1068 individuals. Hence, 1230 children (boys: 600; girls: 630) in the age group of 5-10 years were identified and approached to take part in the investigation. Their dates of birth were checked from the school record and the birth certificates issued by the Government. Socio-economic status (SES) of the children was tested using a revised version of the scale of Kuppuswamy (Mishra and Singh 2003). This scale allows determination of SES based on a score calculated from education, occupation and household income. A total of 140 children (boys: 80; girls: 60) of the 1230 children were excluded from the study as they did not belong to the same SES or their dates of birth were not available or they were not in the age group of 5-10 years. So the final sample comprises 1090 (boy: 520; girls: 570) aged 5-10 years belonging to the same SES (in this case: lower SES) based on the revised scale of Kuppuswamy.

All the children were free from any previous medical and surgical episodes, physical deformity and not suffering from any diseases at the time of data collecting. The parents of the children were informed about the objectives of the study before data collection. The informed consent was collected from the parents and participation of the subjects were voluntary. Data on age, gender, parents' occupation, parents' education, income, family size, family types, house-conditions, electricity facility, sanitary condition and drinking water facilities were collected using pre-structured interview schedule. The present investigation was conducted under the ethical guidelines for human experiments, as laid down the Helsinki Declaration of 2000 (Touitou et al. 2004). The data were collected during the period from September 2015 to March 2016.

Anthropometric measurements recorded

Anthropometric measurements of height and weight were recorded using standard anthropometric procedures. The height of the children was recorded to the nearest 0.1 cm using an anthropometer rod with the head held in the Frankfort horizontal plane. The weight of the children, wearing minimum clothing and bare feet, was taken using a portable weighing scale to the nearest 100 gm. The intra-observer and inter-observer technical errors of measurements (TEM) were calculated to determine the accuracy of the measurements using the standard procedure of Ulijaszek and Kerr (1999).

The TEM was calculated using the following equation:

TEM=$\sqrt{}$ ($\Sigma D^2/2N$), [D=difference between the measurements, N=number of individuals].

The coefficient of reliability (R) was subsequently calculated from TEM using the following equation:

R= {1− $(TEM)^2/SD^2$}, SD= standard deviation of the measurements. For calculating TEM, height, weight, TSF and SSF were recorded by two authors (SD and NM) from 50 children aged 5-10 years other than those selected for the investigation. High values of R (>0.975) were recorded for height and weight. The values were observed being within the acceptable limits of 0.95 as recommended by Ulijaszek and Kerr (1999). Hence, the measurements recorded by SD and NM were being reliable and reproducible. All the measurements during the present investigation were subsequently recorded by one author (SD). Care has been taken to avoid any systematic errors (instrumental or definition of landmarks) in recording the anthropometric measurements as outlined by Harris and Smith (2009).

Assessment of nutritional status

The assessment of nutritional status in the present study was done by using conventional anthropometric indices of wasting, underweight and stunting (WHO 1995; WHO and UNICEF 2009) and CIAF (Svedberg 2000; Nandy et al. 2005). A child having values below −2 SD of the reference median in the indices of stunting, underweight and wasting was classified as undernourished (WHO 1995; WHO 2007; WHO and UNICEF 2009). The combination of Svedberg's (2000) model of six groups (i.e., stunting only, underweight only, wasting only, wasting and underweight, stunting and underweight and stunting, wasting and underweight) and one group (i.e., underweight only) from Nandy et al. (2005) have been used to assess the prevalence of undernutrition. The proposed classification of CIAF for the assessment of undernutrition is presented in Table 1.

TABLE 1. CLASSIFICATION OF CHILDREN WITH ANTHROPOMETRIC FAILURE (CIAF)*

Groups	Description	Wasting	Underweight	Stunting
A	**No Failure**	No	No	No
B	**Wasting only**	Yes	No	No
C	**Wasting and Underweight**	Yes	Yes	No
D	**Wasting, Stunting and Underweight**	Yes	Yes	Yes
E	**Stunting and Underweight**	No	Yes	Yes
F	**Stunting only**	No	No	Yes
Y	**Underweight only**	No	Yes	No

*Classification based on Nandy *et al*. (2005).

Statistical analysis

The statistical analysis was done using the Statistical Package for Social Sciences (SPSS) for Windows (Version 17.0). Chi-square (χ^2) analysis was done to determine sex-specific differences in the overall prevalence of undernutrition and CIAF. The p-values of <0.05 and <0.01 were being statistically significant. Binary logistic regression (BLR) analysis model was fitted to estimate the odds ratios (ORs). 95% confidence intervals (CIs) in BLR were used to examine the effect of the different socio-economic, demographic variables and the CIAF categories. This model is allowed for controlling the different socio-economic and demographic variables by comparing with a reference category. To create the dependency variables, children suffering from anthropometric failures (Groups B–Y) were included in a separate group against normal category. The logistic regression analysis was performed in different combinations of anthropometric failure {eg., single (i.e., B, F and Y), double (i.e., C and E) and multiple (i.e., D)} categories. A child experiencing any form of undernourishment was entered in the logistic model separately. Undernourished children were coded as 1 and normal children were coded as 0. Predictor variables of age, sex, family size, number of sibs, occupation and ethnic groups were entered in the regression equations as a set of dummy variables. Results were calculated by comparing respective reference category. The p-values of <0.05 and <0.01 were statistically significant.

RESULTS

The sex-specific and overall prevalence of wasting, underweight, stunting and CIAF are presented in Table 2. The overall prevalence of wasting, underweight, stunting and CIAF was observed being 15.05%, 35.50%, 29.54% and 48.35%, respectively. It was further revealed that the girls were observed being more affected by wasting (17.02% vs. 12.85%), but boys were more affected by underweight (39.04% vs. 32.28%), stunting (29.81% vs. 29.30%) and CIAF (49.62% vs. 47.19%). The sex-specific difference in the prevalence of undernutrition was observed being not significant using χ^2 analysis ($p>0.05$). The sex-specific prevalence of the children suffering from single and multiple failures of the CIAF (Groups B–Y) are presented in Table 3. Overall, 51.65% of the children (boys: 50.38%; girls: 52.81%) showed no anthropometric failure (i.e., Group A). The CIAF aggregating the children suffering from single, double and multiple failures (i.e., Groups B–Y) showed a high prevalence (48.35%) of undernutrition (boys: 49.62%; girls: 47.19%) (Table 2). The results also showed that the overall prevalence of undernutrition was found being highest in Group E (Overall: 13.39%; Boys: 15.58% and Girls: 11.40%) followed by single failures in Group F (Overall: 10.55%; Boys: 9.42% and Girls: 11.58%). The prevalence was found higher in Group C (Overall: 7.16%; Boys: 6.92% and Girls: 6.92%) than Group D (Overall: 5.60%, Boys: 4.81%, Girls: 6.32%). The prevalence of acute undernutrition (i.e., Group B) (Overall: 2.29%; Boys: 1.15% and Girls: 3.33%) was being higher in girls than boys. It was further observed that the girls were observed being more affected in sex-specific undernutrition in different CIAF categories (i.e., Groups B, C, D and F) than boys, with the exception being in the Group E and Group Y. The overall sex difference in CIAF categories were observed were not significant ($p>0.05$), except in Group B (χ^2-value: 5.51, d.f., 1; $p<0.05$) and Group Y (χ^2-value: 5.46, d.f., 1; $p<0.05$) being significant using χ^2- analysis ($p<0.01$) (Table. 3).

TABLE 2. PREVALENCE OF WASTING, STUNTING, UNDERWEIGHT AND COMPOSITE INDEX OF ANTHROPOMETRIC FAILURE AMONG CHILDREN

Categories	Total (n=1090)	Boys (n=520)	Girls (n=570)	Sex difference	
				χ^2- value	p
Wasting	164 (15.05)	67 (12.85)	97 (17.02)	2.69	0.10
Underweight	387 (35.50)	203 (39.04)	184 (32.28)	2.58	0.11
Stunting	322 (29.54)	155 (29.81)	167 (29.30)	0.02	0.89
CIAF	527 (48.35)	258 (49.62)	269 (47.19)	0.22	0.64

Values are parenthesis indicates percentage; $^{*}p<0.05$; $^{**}p<0.01$

TABLE 3. PREVALENCE OF UNDER-NUTRITION USING DIFFERENT CATEGORIES OF COMPOSITE INDEX OF ANTHROPOMETRIC FAILURE AMONG CHILDREN

Group	Description	Total (n= 1090)	Boys (n = 520)	Girls (n= 570)	Sex difference (χ^2-value)
A	No failure	563 (51.65)	262 (50.38)	301 (52.81)	0.20
B	Wasting only	25 (2.29)	6 (1.15)	19 (3.33)	5.51^{**}
C	Wasting and Underweight	78 (7.16)	36 (6.92)	42 (7.37)	0.07
D	Wasting, Stunting and Underweight	61 (5.60)	25 (4.81)	36 (6.32)	1.05
E	Stunting and Underweight	146 (13.39)	81 (15.58)	65 (11.40)	3.11
F	Stunting only	115 (10.55)	49 (9.42)	66 (11.58)	1.09
Y	Underweight only	102 (9.36)	61 (11.73)	41 (7.19)	5.46^{**}

Values are parenthesis indicates percentage; $^{*}p<0.05$; $^{**}p<0.01$

Effect of Socio-economic and demographic variables with the prevalence of CIAF

Results of the BLR model fitted to estimate the odds ratio of being affected by the single failure (i.e., B, F and Y), double failure (i.e., C and E) and multiple failures (i.e., D) of CIAF with certain socio-economic and demographic variables are shown in Table 4. The results showed that single failure is associated with higher age groups (9-10 years) (odds ratio: 1.67) ($p< 0.01$), birth order (3≥) (odds ratio: 4.74) ($p<0.01$), family size (5≥ individuals) (odds ratio: 1.75) ($p< 0.01$), number of sibs (3≥) (odds ratio: 1.73) ($p< 0.01$), fathers occupation (farmers and labourers) (odds ratio: 2.49) ($p< 0.01$), income head (1 individual) (odds ratio: 1.78) ($p<0.05$), house condition (e.g., non-bricked) (odds ratio: 2.80) ($p< 0.01$) and monthly household income (≤Rupees. 4000) (odds ratio: 2.44) ($p< 0.01$). Doubles failure was observed being significantly associated with age (5-8 years) (odds ratio: 2.28) ($p<0.01$), family size (≥5 individuals) (odds ratio: 2.33) ($p<0.01$), birth order (≥3rd) (odds ratio: 2.11) ($p<0.01$), fathers occupation (farmers and labourers) (odds ratio: 1.42) ($p<0.05$), income head (1 individual) (odds ratio: 4.32) ($p<0.01$), house condition (non-bricked) (odds ratio: 4.70) ($p<0.01$) and monthly household income (≤Rupees. 4000) (odds ratio: 2.34) ($p<0.01$). Multiple failure was significantly associated with father's occupation (farmers and labourers) (odds ratio: 4.87) ($p<0.01$), income head (1 individual) (odds ratio: 2.98) ($p<0.05$) and monthly household income (≤Rupees 4000) (odds ratio: 3.61) ($p<0.05$) (Table. 4).

TABLE 4. BINARY LOGISTIC REGRESSION MODEL ANALYSIS AND ASSOCIATE RISK FACTORS IN DIFFERENT GROUPS OF ANTHROPOMETRIC FAILURES WITH SOCIO-ECONOMIC AND DEMOGRAPHIC VARIABLES AMONG CHILDREN

Characteristics		Frequency (n= 1090)	Single failure (i.e., B, F & Y) (n=242)		Double failure (i.e., C & E) (n= 224)		Multiple failure (i.e., D) (n= 61)	
			Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Sex	Boys	520	1	-	1	-	1.34	0.79-2.26
	Girls	570	1.01	0.76-1.35	1.26	0.94-1.69	1	-
Age	5-8 years	660	1	-	2.28**	1.64-3.18	1.47	0.84-2.56
	9-10 years	430	1.67**	1.25-2.23	1	-	1	-
Family size	≤4 individuals	453	1	-	1	-	1	-
	≥ 5 individuals	637	1.75**	1.29-2.37	2.33**	1.69-3.23	1.19	0.70-2.02
Birth order	1-2	691	1	-	1	-	1.20	0.69-2.07
	≥3rd	399	4.74**	3.50-6.42	2.11**	1.57-2.85	1	-

Contd...

Number of sibs	**1-2**	**593**	1	-	1.05	0.78-1.41	1.22	0.72-2.06
	3≥	**497**	1.73**	1.30-2.31	1	-	1	-
Fathers Occupation	**Farmers and Labours**	**667**	2.49**	1.77-3.52	1.42*	1.05-1.93	4.87**	2.19-10.80
	Business and Service	**423**	1	-	1	-	1	-
Income head in household	**1**	**908**	1.78*	1.51-2.76	4.32**	2.36-7.90	2.98*	1.07-8.32
	≥2	**182**	1	-	1	-	1	-
House condition	**Non-bricked**	**797**	2.80**	1.87-4.16	4.70**	2.90-7.60	1.14	0.62-2.07
	Bricked	**293**	1	-	1	-	1	-
Household Monthly Income	**≤Rupees 4000**	**925**	2.44**	1.48-4.03	2.34**	1.40-3.91	3.61*	1.12-11.67
	≥Rupees 4001	**165**	1	-	1	-	1	-

*p<0.05; **p<0.01

DISCUSSION

The major underlying factors for the prevalence of malnutrition (undernutrition and overnutrition) are attributed to inequalities in resource distribution, poor socio-economic conditions, disease burden and ethnic differences in developing countries (Nandy et al. 2005; Mahgoub et al. 2006; Sen et al. 2012; Mondal et al. 2015; Rengma et al. 2016; Vollmer et al. 2017; Huda et al. 2018). Several research studies have reported that inadequate access to enough food, protective nutrients, healthcare facilities, socio-economic and poor living conditions are the causes of poor nutrition in Indian populations (Nandy et al. 2005; Mukhopadhyay and Biswas 2011; Mondal and Sen 2010; Sen and Mondal 2012; Rengma et al. 2016; Debnath et al. 2018). The conventional anthropometric measures (i.e., wasting, underweight and stunting) are utilised to assess the overall magnitude of undernutrition among children. But these indices cannot estimate the actual burden of undernourishment in the population because of their overlapping nature. These indices only allow for the categorization of children into the general categories of undernourishment. They do not provide an opportunity to determine the overall burden of undernutrition that is associated with multiple anthropometric failures (Svedberg 2000; Nandy et al. 2005; Nandy and Miranda 2008; Nandy and Svedberg 2012; Sen and Mondal 2012; Savanur and Ghugre 2015; Fentahun et al. 2016; Ziba et al. 2017; Kramsapi et al. 2018). Several researchers have reported that CIAF provides an overall estimate of total number of undernourished children in population and is observed to be more useful for estimating overall burden of undernutrition than the conventional anthropometric measures (i.e., wasting, underweight and stunting) (Nandy et al. 2005; Seetharaman et al. 2007; Nandy and Svedberg 2012). Therefore, CIAF is a potential tool for health planners and policymakers to identify the overall magnitude of undernutrition in the vulnerable segments of the population.

The present study has tested the prevalence of undernutrition using both conventional anthropometric measures and CIAF. Overall 50.46% (boys: 51.92%; girls: 48.12%) children were suffering from different grades of anthropometric failure (Table 2). A comparison of undernutrition using conventional anthropometric measures and CIAF among Indian children with the present investigation is depicted in Table 4. The comparison of the prevalence of undernutrition in the present investigation was observed being a lower than the prevalence among the children of Hooghly (73.1%) (Mandal and Bose 2009), urban slum children (73.2%) (Dewan et al. 2015), preschool children of Darjeeling (65.6%) (Mukhopadhyay et al. 2009), children of Darjeeling district (63.6%) (Sen and Mondal 2012) and rural-urban children of Allahabad (62.8%) (Kumar et al. 2010). Also the prevalence was a lower than the children of Delhi (62.0%) (Gupta et al. 2017), children of Agra city (60.0%) (Agarwal et al. 2015), children of Chapra Nadia District (60.4%) (Biswas et al. 2009) and urban Slum children (58.6%) (Dhok and Thakre 2016).

Some other studies also have observed a higher prevalence among the children of Midnapore Town (58.2%) (Sinha and Maiti 2012), Bhumij children (54.4%) (Goswami 2016), Slum children of Coimbatore (68.6%) (Seetharaman et al. 2007), Bauri caste of Purulia district (66.3%) (Das and Bose 2009), Indian children (59.8%) (Nandy et al. 2005), Bengalee Muslim children (57.6%) (Sen et al. 2011) and tribal children of Assam (51.0%) (Kramsapi et al. 2018). The prevalence observed in the present investigation was higher than it is observed in case of Bangalee children (50.2%) (Acharya et al. 2013), urban slum children of Mumbai city (47.8%) (Savanur and Ghugre 2015), Santal ethnic group (43.4%) (Das and Bose 2011), children of Singur Block (32.7%) (Dasgupta et al. 2015). CIAF helps to assess the actual proportions and determine the relative risk of undernutrition in various sub-groups (Groups B–Y). Several studies have proposed that cause-specific mortality and co-morbidity detection could accurately by CIAF (i.e., single or double and/or multiple failure groups). It is not possible in case of conventional anthropometric indices which cannot identify the groups of children with multiple failures (Seetharaman et al. 2007; Mahgoub et al. 2009; Sen et al. 2011; Sen and Mondal 2012; Savanur and Ghugre 2015; Fentahun et al. 2016; Ziba et al. 2017; Kramsapi et al. 2018). The CIAF and its disaggregated groups (i.e., B-Y) gives the comprehensible description of undernutrition, which the conventional indices cannot predict due to their overlapping nature (Nandy et al. 2005; Nandy and Miranda 2008; Seetharaman et al. 2007; Sen and Mondal 2012; Savanur and Ghugre 2015; Fentahun et al. 2016; Ziba et al. 2017; Kramsapi et al. 2018). For the quantification of the relationship between different undernutrition categories (i.e., B-Y) and adverse health outcomes more appropriate anthropometric indicators are necessary rather than the conventional one (Nandy et al. 2005; Sen and Mondal 2012). Studies have observed that multiple anthropometric failures are more likely to be prevalent in Indian children belonging to poor SES (Mukhopadhyay and Biswas 2011). Similar studies have reported that children who were suffering from multiple anthropometric failures (i.e., Group D: stunting, underweight and wasted) had greater socio-economic risk factors for illness and morbidity (Nandy et al. 2005; Fentahun et al. 2016).

The present study has observed significant associations between socio-economic, demographic variables and three different failures (Table 4). Some other studies also have observed similar associations (Kumar et al. 2010; Sen and Mondal 2012; Shit et al. 2012; Khan and Raza 2014; Dasgupta et al. 2015; Fentahun et al. 2016; Endris et al. 2017). Kumar et al. (2010) reported that improvement of the standard of living can improve the situation of overall undernourishment in the country. Low standard of living index is an important risk factor for child undernutrition irrespective of social background (Kumar et al. 2010). A significant association between age, family type, education of mother, birth weight, birth order and morbidity profile with CIAF among children by Dasgupta et al. (2015). Similar findings regarding education level of the mother, type of family, and the number of siblings in the family by Shit et al. (2012). Several studies have shown significant negative associations with wealth index/income status with CIAF among children (Khan and Raza 2014; Pei et al. 2014; Endris et al. 2017; Vollmer et al. 2017). Studies have observed significant associations between age and anthropometric failures as the trend suggests in the present study (Dasgupta et al. 2015; Kherde et al. 2018). Several studies have shown the significant association between undernutrition and family size (Vashisht et al. 2005; Bhanderi and Choudhary 2006; Sen and Mondal 2012). The result of the BLR analysis showed the statistically significant association between CIAF categories (i.e., single failure and double failure) and larger family size ($p<0.05$). Undernutrition among children was strongly correlated with the number of sibs in many studies (Sinnaeve et al. 2006; Mondal and Sen 2010; Sen and Mondal 2012). Similarly, children belonging to ≥3rd birth order category were found to have 4.74 times ($p<0.01$) and 2.11 times ($p<0.01$) times higher risk factors for a single and double anthropometric failures, respectively. Studies have reported that children belonging to the higher birth order categories were found to have higher risk factors of undernutrition (Sen and Mondal 2012; Dasgupta et al. 2015; Khan and Raza 2014; Rengma et al. 2016). Dasgupta et al. (2015) reported that children $\geq 3^{rd}$ birth order had 4.08 times significantly higher risk of CIAF ($p<0.01$).

Research studies have reported that the socio-economic burden on poor families with several children has led mothers to give less attention to their younger children and as a result nutritional status of these children suffers (e.g., Mondal and Sen 2010). The results of the present study showed similar trends in case of a single and double failure with the higher number of sibs. Some other studies have observed significant associations between undernutrition and poor sanitation, fathers occupation, lower number of income head, poor house conditions as observed in the present investigation (Khan and Raza 2014; Tagga et al. 2015a,b; Kumar et al. 2015; Rengma et al. 2016; Galgamuwa et al. 2017). Results of the present investigation showed that non-bricked households have significantly greater odds for the single (Odds: 2.80 times) and double (Odds: 4.70 times) anthropometric failure categories in children ($p<0.01$). Studies also have observed a significant association between house conditions and prevalence of undernutrition (Yuwono 2008; Galgamuwa et al. 2017; Tasnim et al. 2017). Results of BLR analysis showed that children belonging to the 'Farmer and labours' group had significantly higher risks of both single (Odds: 2.49 times; $p<0.05$) and double (Odds: 1.42 times; $p<0.05$) anthropometric failures (Table 4). Father's occupation also observed being associated with nutritional status of children in many studies as observed in the present investigation (Tigga et al. 2015; Rengma et al. 2016; Ritu et al. 2018). The results of the present study showed that the risk of single (Odds: 2.44 times), double (Odds: 2.34 times) and multiple (Odds: 3.61 times) CIAF categories were significantly higher in children belonging to low-income households (i.e., ≤Rupees 4000) ($p<0.01$) (Table 4). Therefore, the segregation of the CIAF categories serves an important aspect related to the identification of multiple categories of undernourishment (e.g., C, D and E) (Nandy et al. 2005; Sen and Mondal 2012; Kramsapi et al. 2018).

CONCLUSION

The present study shows a serious problem of child undernourishment using CIAF. The CIAF can be an essential component of monitoring of the nutritional status of children in epidemiological or clinical settings for assessing of the actual magnitude of undernutrition. The assessment of multiple anthropometric failures will help to reduce or identify the relative risk of mortality and morbidity in children. Several socio-economic, demographic and lifestyle factors were being significantly associated with three different anthropometric failures in children. Therefore, the overall improvement of the socio-economic status and lifestyle is necessary to improve the nutritional conditions in population. Also, the identification of the important socio-economic and demographic variables is necessary for determining the risk associated with different categories of CIAF. More studies are necessary among children from different parts of the country for getting a broader representation using CIAF. A large Indian population inhabits in rural India where the magnitude of childhood undernutrition is high. It will immensely help the determination of the actual child undernutrition burden among children. Such studies will be helpful for measuring the aggregate value of prevailing undernourishment. There is an urgent need of appropriate nutritional intervention programme to improve the nutritional status of the children.

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ABBREVIATED TITLE

Composite Index of Anthropometric Failure among Indian Children

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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ETHICAL APPROVAL

The investigation was conducted in accordance with the ethical guidelines for human experiments, as laid down in the Helsinki Declaration of 2000. Research permission to conduct the present investigation was obtained from the Department of Anthropology, University of North Bengal.

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