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Burden of Anthropometric Failures among pre-school children (<5 years) in India: A Nutrition Paradox

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ABSTRACT

Undernutrition is a very significant public health concern in many developing countries. Undernutrition in children under five years of age is one of the most serious health problems in developing countries including India. The conventional anthropometric measures of height-for-age (stunting), weight-for-age (underweight) and weight-for-height (wasting) are used to assess the undernutrition status, but these measures understate the actual magnitude of undernutrition because of overlapping in nature in population. Several researchers have further suggested that conventional anthropometric indices could not provide the overall prevalence of undernutrition as the researcher had to 'choose' a certain category of anthropometric failure when assessing nutritional status. The composite index of anthropometric failure (CIAF) is a proposed alternate anthropometric measure to assess the magnitude of undernutrition in children. The CIAF comprises typical anthropometric indicators and their combination (i.e., an aggregate index) into seven categories and proposes an additional measure to study undernutrition as an alternative to the evaluation of stunting, wasting and underweight as the separate measure. Therefore, this could be a potential tool to health planners and policymakers - considering the CIAF to assess the actual burden of undernutrition in the most vulnerable segment of the population. Hence, it is imperative to assess the magnitude of undernutrition to implement intervention programme for reducing the actual burden on the population. The objectives of the present review paper are to evaluate and compare the present situation of undernutrition reported using both conventional anthropometric measures and CIAF among Indian children (<5 years). The present review paper has also emphasized the potential advantages of CIAF over the used conventional anthropometric measures because it determines comprehensive anthropometric failure in a very magnificent way. The disaggregation of CIAF categories provides more accurate identification of nutritional risks in both double or multiple anthropometric failures and actual magnitude of undernutrition than used conventional anthropometric measures among Indian children (<5 years). Therefore, this proposed alternative anthropometric measure (i.e., CIAF) will be helpful to identify actual vulnerable segments or at-risk children and also to plan target specific appropriate nutritional intervention policies and/or need-based aid in ongoing intervention programmes to reduce the actual burden of malnutrition in population.

Keyword: Anthropometry, 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, 2013; Nandy et al., 2005; Ramachandran, 2014). Globally, the prevalence of undernutrition is being the principal cause of mortality (i.e., 45.0%) among children (<5 years) (Black et al., 2013; Ramachandran, 2014) and the leading cause of death among childrenin the developing countries (UNICEF, 1998; WHO, 2001; Debnath et al., 2017). United Nations Children's Fund reported the level of child undernutrition is about 90% in the developing world's chronically undernourished (i.e., stunted or low height-for-age) children which living only in Asia and Africa (UNICEF-WHO-The World Bank Joint Child Malnutrition Estimates,2012, 2018). In India about 20 % of children (<5 years) are suffering from wasting (low weight-for-height) due to presence of acute undernutrition. National Family Health Survey (NFHS) data showed that more than one third of the wasted children in the world are lives in India and recent data showed that the 43% of Indian children (<5 years) were suffering from underweight (low weight-for-age) and 48 % (i.e. 61 million children) are stunted due to the presence of chronic undernutrition and very sadly India is accounting for more than 3 children out of every 10 stunted children in the world (NFHS-3, 2005-2006).

India has been witnessing highest prevalence of global childhood undernutrition burden (Svedberg, 2011; UNICEF, 2013). Poverty, socio-economic inequalities and demographic conditions are being the major underlying causes of undernutrition in the country (Nandy et al., 2005; Antony and Laxmaiah, 2008; Mondal and Sen, 2010; Ahmed et al., 2012; Vardharajan et al., 2013; Ramachandran, 2014; Rengma et al., 2017; Debnath et al., 2018). Moreover, cultural practices, gender disparities and access to healthcare amenities are the important contributors to undernourishment among female children (Sen and Mondal, 2012; Acharya et al., 2013; Solanki et al., 2014; Kshatriya and Acharya, 2016; Daral et al., 2017; Debnath et al., 2018). Several researchers have reported that girls are found to be nutritionally vulnerable than boys (Bose et al., 2007; Mondal and Sen, 2010; Sen and Mondal, 2012; Tigga et al., 2015a,b; Angadi et al., 2017; Newman, 2017; Debnath et al., 2018). According to India Health Report: Nutrition (Raykar et al., 2015) showed that 38.7% of Indian children (<5 years) were stunted, 19.8% were wasted and 42.5% were underweight, Stunting is a measure of chronic undernutrition; wasting indicates acute undernutrition; and underweight is a composite of these two conditions. A prevalence of underweight above 30.0% and wasting above 10% are considered serious public health problems (WHO 1995). India contributes to one-third of severely wasted (low weight-for-height) children (i.e., <5 years) in the world. Recent metaanalysis of 41 studies on Indian tribal children which revealed the average rate of prevalence of underweight, stunting and wasting among the preschool tribal children of India was 42.96%; 44.82% and 23.69% (Dey and Bisai, 2019). Moreover, India has witnessed a significant economic development, but still is suffering from the opposite side of energy balance, where the prevalence of overweight and obesity have increased in urban regions, and also facing major challenges due to the persisting public health problem of child (<5 years) undernutrition (>40.0%) in the country (NFHS-3, 2005-2006; Antony and Laxmaiah, 2008; Mondal and Sen, 2010; Vardharajan et al., 2013; Ramachandran, 2014; Mondal et al., 2015; Debnath et al., 2018; Bharali et al., 2019).

ANTHROPOMETRIC ASSESSMENT OF CHILD NUTRITIONAL STATUS

Body dimensions and composition change reflects the aggregated health situation and welfare of individual/population. Anthropometric measures are widely used non-invasive, inexpensive, reliable and accepted technique to predict the health performance, survival and nutritional status and also most useful to directing policy (WHO, 1995; Hall et al., 2007; Svedberg, 2011). Prevalence of undernutrition increase the relative risks of different mortality and morbidity in children (<5 years) (Pelletier et al., 1995; Nandy et al., 2005; Black et al., 2013; Asfaw et al., 2015; Liu et al., 2015; Debnath et al., 2017; Bhutta et al., 2017). The prevalence of undernutrition/malnutrition is most widely assessed using conventional anthropometric measures [i.e., stunting, underweight (low weight-for-age), wasting and thinness (low body mass index (BMI)-for-age)] (WHO, 1995, 2007; Nandy et al., 2005; Hall et al., 2007; Mondal and Sen, 2010; Svedberg, 2011; Sen and Mondal, 2012) (Table 2). The interpretation/assessment of undernutrition based on these recommended conventional anthropometric measures considered to be <−2SD or <−2.00 Z-score of the reference population (e.g., WHO, 1995, 2007). These conventional anthropometric measures reflect distinct but prominent biological processes, but unsuccessful to reflect the overall magnitude of undernourishment especially when experienced multiple anthropometric failures or deficits among children (e.g., <5 years) (e.g., Svedberg, 2000; Nandy et al., 2005; Sen et al., 2011; Nandy and Svedberg, 2012; Agarwal et al., 2015; Dasgupta et al., 2015; Kramsapi et al., 2018; Bharali et al., 2019). Moreover, the assessment of actual burden of undernutrition is necessary meet the national/international target in nutrition, mainly focusing on the nutritional assessment, formulation of appropriate or target specific nutritional intervention programme, evaluate efficacy and coverage of ongoing nutritional intervention programme in population (WHO, 1995; Nandy et al., 2005; Svedberg, 2011; Mondal and Sen, 2012; Ziba et al., 2018; Bharali et al., 2019).

ASSESSMENT OF COMPOSITE INDEX OF ANTHROPOMETRIC FAILURE

The nutritional situation in the present paper was evaluated by using conventional anthropometric measures of wasting, underweight and stunting (WHO, 1995; WHO and UNICEF, 2009) and Composite Index of Anthropometric Failures (CIAF) (Svedberg, 2000; Nandy et al., 2005). A child having values <−2 SD of the reference median or <-2.00 Z-score 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 (stunting only, underweight only, wasting only, wasting and underweight, stunting and underweight and stunting, wasting and underweight) and one group (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. The CIAF is now being adopted by researchers to identify the aggregate level of undernutrition among children. The assessment of undernutrition was found to be more often greater in CIAF than the values determined by conventional anthropometric measures (i.e., stunting, underweight and wasting) (Nandy et al., 2005; Nandy and Miranda, 2008; Svedberg, 2011; Sen and Mondal, 2012; Nandy and Svedberg, 2012; Ziba et al., 2018; Bharali et al., 2019) (Table 2). The conventional anthropometric measures (i.e., wasting, underweight and stunting) are utilised to assess the overall magnitude of undernutrition among children, but these anthropometric indices are unable to estimate the actual burden of undernourishment in the population because of their overlapping nature (Svedberg, 2000, 2011; Nandy et al., 2005; Berger et al., 2008; Nandy and Miranda, 2008; Nandy and Svedberg, 2012; Bharali et al., 2019). 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; Berger et al., 2008; Nandy and Miranda, 2008; Nandy and Svedberg, 2012; Sen and Mondal, 2012; Savanur and Ghugre, 2015; Fentahun et al., 2016; Ziba et al., 2018; 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.

Table 1. Classification of anthropometric failure assessed by *Composite Index of Anthropometric Failure* (CIAF)*

Group name	Description	Wasting	Stunting	Underweight
A	No failure: Children whose height and weight are above the age-specific norm (i.e. above – 2 z-scores) and do not suffer from any anthropometric failure.	No	No	No
B	Wasting only: Children with acceptable weight and height for their age but who have subnormal weight for height.	Yes	No	No
C	Wasting and underweight: Children with above-norm heights but whose weight for age and weight for height are too low.	Yes	No	Yes
D	Wasting, stunting and underweight: Children who suffer from anthropometric failure on all three measures.	Yes	Yes	Yes
E	Stunting and underweight: Children with low weight for age and low height for age but who have acceptable weight for their height.	No	Yes	Yes
F	Stunting only: Children with low height for age but who have acceptable weight, both to their age and for their short height.	No	Yes	No
Y	Underweight only: Children who are only underweight.	No	No	Yes

* Classification based on Nandy et al. (2005)

NUTRITIONAL ASSESSMENT STUDIES DONE UISNG COMPOSITE INDEX OF ANTHROPOMETRIC FAILURES AMONG INDIAN CHILDREN

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., 2018). 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; Bharali et al., 2019). 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., 2011; Sen and Mondal 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; Bharali et al., 2019). 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 and Mondal, 2012; Poluk et al., 2016; Mondal et al., 2015; Debnath et al., 2018; Kramsapi et al., 2018). Several researchers have also reported high 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; Vollmer et al., 2017; Kherde et al., 2018; Bharali et al., 2019).

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. The comparisons of undernutrition using conventional anthropometric measures and CIAF between various investigations among Indian children were depicted in Table 2 and 3. The comparison of the prevalence of undernutrition in the present paper was observed being a higher among the Indian children (59.8%) (Nandy et al., 2005), Slum children of Coimbatore (68.6%) (Seetharaman et al., 2007), Bauri caste of Purulia district (66.3%) (Das and Bose, 2009), Hooghly (73.1%) (Mandal and Bose, 2009), children of Chapra Nadia District (60.4%) (Biswas et al., 2009), pre-school children of Darjeeling (65.6%) (Mukhopadhyay et al., 2009), Bankura, West Bengal (69.1%) (Mukhopadhya and Biswas, 2010), rural-urban children of Allahabad (62.8%) (Kumar et al., 2010), Santal ethnic group (43.4%) (Das and Bose, 2011), Muslim children (57.6%) (Sen et al., 2011) children of Darjeeling district (63.6%) (Sen and Mondal, 2012).Some other studies also have observed a higher prevalence among the children of Midnapore Town (58.2%) (Sinha and Maiti, 2012), the prevalence was also observed higher in following studies; Bangalee children (50.2%) (Acharya et al., 2013), Varanasi, India (62.5%) (Anwar et al., 2013), Melghat, Cenral India (76.3%) (Talapalliwar and Garg, 2014), Ahmedabad (60.5%) (Solanki et al., 2014), urban slum children of Mumbai city (47.8%) (Savanur and Ghugre, 2015), Ballabgarh, Haryana (53.1%) (Gupta et al. 2015), Raipur, Chattisgarh (62.1%) (Boregowda et al. 2015), Kolkata, West Bengal, (47.3%) (Sarkar et al., 2015), children of Agra city (60.0%) (Agarwal et al., 2015), in Jammu children (73.2%) (Dewan et al., 2015), and urban Slum children (58.6%) (Dhok and Thakre, 2016). Bhumij children (54.4%) (Goswami, 2016), Banglore, India (51.8%) (Keri et al., 2016), Hooghly, West Bengal (47.6%) (Manjula et al., 2017), Delhi (62.0%) (Gupta et al., 2017), Hooghly, West Bengal (57.8%) (Daral et al., 2017), Ahmedabad (73.4%) (Rastogi et al., 2017), Kottayam, Kerala (45.7%) (Jayalakshmi and Jissa, 2017), tribal children of Assam (51.0%) (Kramsapi et al., 2018), South 24 Pargana West Bengal (61.3%) (Biswas et al. 2018), Visakhapatnam, Andhra Pradesh (56.0%) (Namburi and Seepana, 2018), Pune, Maharastra (75.3%) (Rasheed and Jeyakumar, 2018), Nagpur, Maharastra (48.5%) (Kherede et al., 2018), Lakhimpur, Assam (48.6%) (Bharali et al., 2019), Tiruchirappalli, Tamil Nadu, India (85.0%) (Prabhakar et al., 2019)(Table 3).However, there are very few studies where the prevalence was foundto be lower among the children includes Singur Block (32.7%) (Dasgupta et al., 2015) Kashmir, India (30.35%) (Anjum et al., 2012), Singur, West Bengal (36.1%) (Roy et al., 2018). The CIAF prevalence was 47.5% in 1990–2000 and declined to 42.6% in 2001–2014 on 39 countries including India (Vollmer et al., 2017).

Similarly not only in Indian studies, CIAF was also a preferable indicator in various international studies. There are various studies reported from various countries estimate a very prevalence of undernutrition by using CIAF criteria's , study conducted by (Berger et al., 2008) on Kenya reported CIAF (38.2%), (Khan and Azid, 2011) reported in Pakistan (38.7%), (Bejerano et al., 2014) in Jujuy, Argentina wherethe CIAF for highland children (6.1%) and for lowland children (3.4%) which is higher than the single group of anthropometric failure (i.e. Stunting , underweight, wasting). Studies have reported high prevalence of CIAF from Oyestate, Nigeria (Olukemi et al., 2014) reported 47.5%, rural Ethopia 48.5% (Endris et al., 2017), reported 27.41% in Thailand (Sapkota et al., 2018) and very recent studies carried out in South Yemen (Al-Sadeeq et al., 2019) (70.1%) and another (Femelia et al., 2019) (51.4%) in Indonesia. The CIAF helps to assess the actual proportions and determine the relative risk of undernutrition in various sub-groups with single double and multiple anthropometric failures in seven categories (Groups B–Y). In these categories (Group-A) is considered as not failure where (Group-B, E& Y) were considered as single failure, (Group-C& E) is double and (Group-D) is considered as multiple and most severe failure (Table 4). Various studies reported a very high frequency of prevalence (Wasting, Stunting and Underweight together) of multiple failures in preschool children (Group-D) of Pune, Maharastra (30.8%) (Rasheed and Jeyakumar, 2018), Odisha (16.2%) (Goswami, 2016), Ahmedabad, (16.00%) (Rastogi et al., 2017), Bankura, West Bengal (13.7%) (Shit et al. 2012), Melghat, Cenral India (13.00%) (Talapalliwar and Garg, 2014), Varanasi, India (12.4%) (Anwar et al., 2013), West Bengal, (11.2%) (Das and Bose, 2009), Darjeeling, West Bengal (11.1%) (Sen and Mondal, 2012) and Hooghly, West Bengal (10.7%) (Mandal and Bose, 2009). Whereas the lower prevalence was reported in Lakhimpur, Assam (1.9%) (Bharali et al., 2019), Narpur, India (2.61%) (Kherde et al. 2018), Ballabgarh, Haryana (3.1%) (Gupta et al. 2015), Kolkata, West Bengal (3.3%) (Sarkar et al., 2015) and Bankura, West Bengal (3.49%) (Patsa and Banerjee, 2018)(Table 4).

SOCIO-ECONOMIC AND DEMOGRAPHIC VARIABLES ASSOCIATION WITH COMPOSITE INDEX OF ANTHROPOMETRIC FAILURES AMONG CHILDREN

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 (e.g., Nandy et al., 2005; Mahgoub et al., 2006; Sen and Mondal, 2012; Mondal et al., 2015; Rengma et al., 2016; Vollmer et al., 2017; Huda et al., 2018). Several investigations 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;MondalandSen, 2010; Kumar et al., 2010; Mukhopadhyay and Biswas, 2011; Sen and Mondal, 2012; Shit et al., 2012; Khan and Raza, 2014; Dasgupta et al., 2015; Fentahun et al., 2016; Rengma et al., 2016; Endris et al., 2017; Debnath et al., 2018; Bharali et al., 2019). 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). Dasgupta et al. (2015) reported a significant association between age, family type, education of mother, birth weight, birth order and morbidity profile with CIAF among children (<5 years). 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). Several studies have also reported the significant associations between age and anthropometric failures among children (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). 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). 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., 2014; Khan and Raza, 2014; Rengma et al., 2016). Dasgupta et al. (2014) reported that children $\geq 3^{rd}$ birth order had 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 in terms of different anthropometric failures (e.g., Nandy et al. 2005; Das and Bose, 2009; Mondal and Sen, 2010; Shit et al. 2012; Acharaya et al. 2013, Dewan et al. 2015; Kramsapi et al. 2018; Bharali et al., 2019). Research investigations have also shown significant associations with prevalence of anthropometric failures in case of a single and double failure and the higher number of sibs (e.g., Sen and Mondal, 2012; Khan and Raza, 2014). Some other studies have observed significant associations between undernutrition and poor sanitation, fathers occupation, lower income of head, poor house conditions as observed in the present investigation (Som et al. 2006; Rahman et al. 2009; Babar et al. 2010; Acharya et al. 2013; Khan and Raza, 2014; Tagga et al., 2015a,b; Kumar et al., 2015; Rengma et al., 2016; Galgamuwa et al., 2017;Patsa and Banerjee, 2018). Studies also have observed a significant association between house conditions and prevalence of undernutrition (e.g., Galgamuwa et al., 2017; Tansim et al., 2017). 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).

POTENTIAL ADVANTAGES OF COMPOSITE INDEX OF ANTHROPOMETRIC FAILURE OVER CONVENTIONAL MEASURES IN ASSESSMENT OF UNDERNUTRITION

Several research investigations have proposed that cause-specific mortality and co-morbidity detection could be accurately done by the CIAF (i.e., single or double and/or multiple failure groups). It is not possible in case of conventional anthropometric indices which cannotable to identify the groups of children with multiple failures (Nandy et al., 2005;

Mahgoub et al., 2006; Seetharaman et al., 2007; Nandy and Miranda, 2008; Sen et al., 2011; Svedberg, 2011; Nandy and Svedberg, 2012; 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 categories (i.e., B-Y) provides the comprehensible descriptions of undernutrition assessment (Table 1), which the conventional indices cannot able to predict due to their overlapping nature (Nandy et al., 2005; Nandy and Miranda, 2008; Seetharaman et al., 2007; Nandy and Svedberg, 2012; Sen and Mondal, 2012; Savanur and Ghugre, 2015; Fentahun et al., 2016; Ziba et al., 2017; Kramsapi et al., 2018; Bharali et al., 2019). For the quantification of the relationship between different undernutrition categories (i.e., B-Y) and adverse health outcomes (e.g., morbidity and mortality)are more appropriate anthropometric indicators are necessary rather than the conventional anthropometric measures (Nandy et al., 2005; Deshmukh et al., 2009; Sen and Mondal, 2012; Bharali et al., 2019). Several nutritional investigations have reported the higher magnitude of undernourishment assessed using CIAF over conventional anthropometric measures, thus indicates the potential advantage to identify the actual burden of undernutrition among Indian preschool children (Nandy et al., 2005; Seetharam et al., 2007; Das and Bose, 2009; Biswas et al., 2009; Boregowda et al., 2015; Savanur and Ghugre, 2015; Dewan et al., 2016; Dhok and Thakre, 2016; Gupta et al., 2017; Kramsapi et al., 2018; Bharali et al., 2019) (Table 2 & 3). Studies have observed that multiple anthropometric failures are more likely to be prevalent in Indian children belonging to poor SES (Mukhopadhyay and Biswas, 2011; Sen and Mondal, 2012; Bharali et al., 2019). 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; Deshmukh et al., 2009; Fentahun et al., 2016). Evaluation of the effects of different socio-economic, demographic and lifestyle factors on CIAF are considered to be necessary to identify the nutritional vulnerability of children. Special attention is required towards health inequalities during the early age of childhood (e.g., <5 years) 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, B-Y) and socio-economic, demographic and lifestyle variables in population. 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 on-going nutritional intervention programmes.

CONCLUSION

The present manuscript has shown the prevalence ofchild undernutrition is an existing serious public health problem in Indian children. The CIAF can be an essential component of assessment and monitoring of the actual magnitude of undernutrition status in epidemiological or clinical settings in population. The assessment of multiple anthropometric failures will be helpful to reduce or identify the relative risk of mortality and morbidity in children (<5 years). Several socio-economic, demographic and lifestyle factors were being significantly associated with different single, double and multiple anthropometric failures. Therefore, the overall improvements of the socio-economic, demographic and lifestyle factorsare necessary to get better the nutritional conditions in population. The identifications of the important socio-economic and demographic variables are necessary to determine the nutritional vulnerability associated with different anthropometric failure categories of CIAF. More studies are necessary among preschool children from different parts of the country for getting a broader representation in order to provide a holistic picture of undernutrition. It will immensely help the determination of the actual undernutrition burden among children. Such studies will be helpful for measuring the aggregate value of prevailing undernourishment and thus, an urgent need of appropriate nutritional programme to improve the nutritional status of the children.

RECOMMENDATIONS

The present review manuscript has discussed the importance and possible advantages of CIAF over the conventional anthropometric measures (i.e., stunting, underweight and wasting) in the assessment of undernutrition status due to its non-invasive, inexpensive and easy-to-use nature in epidemiological and clinical settings among pre-school children (<5 years). The following recommendations are made:

1. Nutritional assessment studies are necessary to evaluate and report the overall magnitude and also compare the undernourishment using the conventional anthropometric measures of height-for-age, weight for age, weight-for-height and CIAF among different vulnerable populations. These anthropometric measures are widely used to assess the undernutrition status due to non-invasive, inexpensive and easy-to-use nature in clinical and epidemiological investigations. Moreover, the early detection of undernutrition will reduce the relative nutritional risks, poor physical growth and development attainments, relative disease burden and premature mortality among children (<5years).
2. The anthropometric measurement provides the indirect assessment of nutritional status of individual/population. Towards the assessment of undernutrition (i.e., stunting,

underweight and wasting) and identifying multiple anthropometric failures in terms of CIAF is more reliable, now from around 10-15 years the CIAF is the most preferable measure to access the actual magnitude and severity of undernutrition with single, double and multiple anthropometric failure amongchildren (<5 years).

3. The CIAF is considered to be a most reliable indicator over the conventional anthropometric measures of nutritional status assessment among children. Therefore, the different health agencies (e.g., NFHS, UNICEF, WHO, National Institute of Nutrition and Indian Council of Medical Research), should thus, the use of CIAF at the national or international level as a step towards reducing the overall burden of undernourishment in children (<5 years). Moreover, the CIAF is the most rigid anthropometric indicator of access the most critical state of undernutrition in children because it shows a multiple (e.g., Group D) prevalence of anthropometric failure in a single child which leads toill-health condition, abnormalities and deficiencies and disease risk identifications.
4. Multi-faceted approach to ensure the better healthcare by health camps to providecomprehensive health-care facilities including varied medical service should be organized at regular intervals in the population/community levels and Integrated Child Development Service (ICDS)centers in order to check or reduce to risk of inadequate nutrition and related morbidities in children. These camps should provide free medical diagnosis, medicines, counseling and management to prevent timely physical growth and nutritional deficiencies due to infections, diseases and faulty feeding practices andshould include pediatricians, dieticians and nutritionists.
5. Government and non-Government agencies to disseminate the knowledge related to nutritional requirements, appropriate feeding and dietary consumptions, health and hygiene practices, physical growth and nutritional risks, during the infancy, early childhood and pregnancy periods among the parents/ women to prevent the relative risk of undernutrition and poor intra-uterine growth retardations (e.g., LBW). Moreover, creating appropriate nutritional and health-related awareness will help to improve the better quality of life among the preschool children (<5 years).

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Table 2. Prevalence of stunting, underweight, wasting among Indian pre-school children (<5 years)

Sl No.	Studies	Publication	Stunting	Underweight	Wasting
1.	India (Nandy et al., 2005)	2005	45.2	47.1	15.9
2.	Coimbatore (Seetharaman et al., 2007)	2007	49.6	46.7	20.2
3.	West Bengal (Das and Bose, 2009)	2009	39.2	51.2	26.6
4.	Hooghly, West Bengal (Mandal and Bose, 2009)	2009	50	63.3	26.6
5.	Nadia, West Bengal (Biswas et al., 2009)	2009	48.2	48.3	10.6
6.	Darjeeling, West Bengal (Mukhopadhya et al., 2009)	2009	46.9	52.3	15.2
7.	Allahabad (Kumar et al., 2010)	2010	49.1	40.7	14.6
8.	Bankura, West Bengal (Mukhopadhya and Biswas, 2010)	2010	50	53.1	20.2
9.	North Bengal, West Bengal (Sen et al., 2011)	2011	38.5	47	17.4
10.	Purulia, West Bengal (Das and Bose, 2011)	2011	26.3	38.2	12.7
11.	Darjeeling, West Bengal (Sen and Mondal, 2012)	2012	43.3	52	21.5
12.	Midnapore, West Bengal (Sinha and Maiti, 2012)	2012	40.58	43.77	23.4
13.	Kashmir, India (Anjum et al., 2012)	2012	8.9	10.73	15.29
14.	PurbaMedinipur, West Bengal (Acharya et al., 2013)	2013	30.7	42.7	12
15.	Varanasi, India (Anwar et al., 2013)	2013	43.1	31.5	35.2
16.	Melghat, Cenral India (Talapalliwar and Garg, 2014)	2014	66.4	60.9	18.8
17.	Ahmedabad (Solanki et al., 2014)	2014	50	42.74	15.05
18.	Singur, West Bengal (Dasgupta et al., 2014)	2014	17.7	15	17.7
19.	Agra, Uttar Pradesh (Agarwal et al., 2015)	2015	41.9	42.8	22.7
20.	Ballabgarh, Haryana (Gupta et al., 2015)	2015	46.2	25.3	9.5

21.	Raipur, Chattisgarh (Boregowda et al., 2015)	2015	46.8	45.2	17.8
22.	Mumbai, Maharastra (Savanur and Ghugre, 2015)	2015	33.8	35.6	18.5
23.	Kolkata, West Bengal (Sarkar et al., 2015)	2015	27.47	40.66	17.58
24.	Jammu, India (Dewan et al., 2015)	2016	42.8	38.8	20.4
25.	Nagpur, Central India (Dhok and Thakre, 2016)	2016	34.77	45.31	15.23
26.	Odisha (Goswami, 2016)	2016	32.6	42.6	25
27.	Delhi (Gupta et al., 2017)	2017	43	35	25
28.	Hooghly, West Bengal (Manjula et al., 2017)	2017	28.2	25.7	27.5
29.	KarbiAnglong, Assam (Kramsapi et al., 2018)	2018	35.5	26.75	18.5
30.	South 24 Pargana, West Bengal (Biswas et al., 2018)	2018	26.2	51.1	35.4
31.	Visakhapatnam,Andhra Pradesh (Namburi and Seepana, 2018)	2018	36	37	22
32.	Pune, Maharastra (Rasheed and Jeyakumar, 2018)	2018	58	34	29
33.	Singur, West Bengal (Roy et al., 2018)	2018	16.7	29.2	22.2
34.	Kottayam, Kerala (Jayalakshmi and Jissa, 2017)	2018	13.4	38.8	30.7
35.	Bankura, West Bengal (Patsa and Banerjee, 2018)	2018	22.09	29.06	13.95
36.	Lakhimpur, Assam (Bharali et al.,2019)	2019	11.60	22.93	36.19

Table 3. Overall prevalence of CIAF in Indian preschool children (<5 years)

Sl. No	Studied Area	**Publication**	**CIAF**	**References**
1.	India	2005	59.8	Nandy et al., 2005
2.	Coimbatore	2017	68.6	Seetharam et al., 2007
3.	West Bengal	2009	66.3	Das and Bose, 2009
4.	Hooghly, West Bengal	2009	73.1	Mandal and Bose, 2009
5.	Nadia, West Bengal	2009	61.4	Biswas et al., 2009
6.	Darjeeling, West Bengal	2009	65.2	Mukhopadhya et al., 2009)
7.	Allahabad	2010	62.8	Kumar et al., 2010
8.	Bankura, West Bengal	2010	69.1	Mukhopadhya and Biswas, 2010
9.	North Bengal, West Bengal	2011	57.6	Sen et al., 2011
10.	Purulia, West Bengal	2011	43.4	Das and Bose, 2011
11.	Darjeeling, West Bengal	2012	63.3	Sen and Mondal, 2012
12.	Midnapore, West Bengal	2012	58.21	Sinha and Maiti, 2012
13.	Kashmir, India	2012	30.35	Anjum et al., 2012
14.	PurbaMedinipur, West Bengal	2013	50.2	Acharya et al., 2013
15.	Varanasi, India	2013	62.5	Anwar et al., 2013
16.	Melghat, Cenral India	2014	76.3	Talapalliwar and Garg, 2014
17.	Ahmedabad	2014	60.5	Solanki et al., 2014
18.	Singur, West Bengal	2014	32.7	Dasgupta et al., 2014
19.	Agra, Uttar Pradesh	2015	60.04	Agarwal et al., 2015
20.	Ballabgarh, Haryana	2015	53.1	Gupta et al., 2015
21.	Raipur, Chattisgarh	2015	62.1	Boregowda et al., 2015
22.	Mumbai, Maharastra	2015	47.8	Savanur and Ghugre, 2015
23.	Kolkata, West Bengal	2015	47.3	Sarkar et al., 2015
24.	Jammu, India	2016	73.2	Dewan et al., 2015

25.	Nagpur, Central India	2016	58.59	Dhok and Thakre, 2016
26.	Odisha	2016	54.5	Goswami, 2016
27.	Banglore, India	2016	51.8	Keri et al., 2016
28.	Delhi	2017	62	Gupta et al., 2017
29.	Hooghly, West Bengal	2017	47.6	Manjula et al., 2017
30.	Delhi,India	2017	57.8	Daral et al., 2017
31.	Ahmedabad	2017	73.4	Rastogi et al., 2017
32.	KarbiAnglong, Assam	2018	51	Kramsapi et al., 2018
33.	South 24 Pargana, West Bengal	2018	61.3	Biswas et al., 2018
34.	Visakhapatnam,Andhra Pradesh	2018	56	Namburi and Seepana, 2018
35.	Pune, Maharastra	2018	75.3	Rasheed and Jeyakumar, 2018
36.	Singur, West Bengal	2018	36.1	Roy et al., 2018
37.	Kottayam, Kerala	2018	45.7	Jayalakshmi and Jissa, 2017
38.	Bankura, West Bengal	2018	40.7	Patsa and Banerjee, 2018
39.	Nagpur,Maharastra	2018	48.5	Kherede et al., 2018
40.	Visakhapatnam, Andhra Pradesh, India	2018	56.0	Nambari and Seepana , 2018
41.	Lakhimpur, Assam	2019	48.62	Bharali et al.,2019
42.	Tiruchirappalli, Tamil Nadu, India	2019	85.00	Prabhakar et al., 2019

Table 4.Comparison of undernutrition prevalence in different categories of anthropometric failure (CIAF) in Indian children

Studies (References)	Publication	Group-A	Group-B	Group-C	Group-D	Group-E	Group-F	Group-Y	TOTAL	CIAF= B-Y
India (Nandy et al., 2005)	2005	40.2	2.6	6.1	7.2	27.9	10.1	5.9	100	59.8
Coimbatore (Seetharam et al., 2007)	2007	31.4	2.7	11.9	5.7	24.7	19.3	4.4	100.1	68.7
West Bengal (Das and Bose, 2009)	2009	33.7	7.5	8.4	11.2	25.4	7.2	6.6	100	66.3
Hooghly, West Bengal (Mandal and Bose, 2009)	2009	26.9	7.2	32	10.7	13.4	2.7	7.1	100	73.1
Nadia, West Bengal (Biswas et al., 2009)	2009	39.6	0.74	4.17	5.65	31.2	11.36	7.2	99.92	60.32
Allahabad (Kumar et al., 2010)	2010	37.2	2.4	6.2	5.9	23.5	11.3	13.5	100	62.8
Bankura, West Bengal (Mukhopadhya and Biswas, 2010)	2010	30.9	3.2	8.5	8.5	28.7	12.8	7.4	100	69.1
North Bengal, West Bengal (Sen et al., 2011)	2011	42.43	5.16	6.39	5.86	27.21	5.42	7.52	99.99	57.56
Bankura, West Bengal (Shit et al., 2012)	2012	19.7	0.8	4.3	13.7	24.8	33.3	3.4	100	80.3
Darjeeling, West Bengal (Sen and Mondal, 2012)	2012	36.5	3.7	7	11.1	26.9	7.4	7.3	99.9	63.4
Midnapore, West Bengal (Sinha and Maiti, 2012)	2012	41.79	4.1	9.57	9.73	20.52	10.33	3.95	99.99	58.2
PurbaMedinipur, West Bengal (Acharya et al., 2013)	2013	49.8	0.9	5.8	5.3	18.7	6.7	12.9	100.1	50.3
Varanasi, India (Anwar et al., 2013)	2013	37.5	11.2	7.9	12.4	14.5	16.1	0.4	100	62.5
Melghat, Cenral India (Talapalliwar and Garg, 2014)	2014	23.7	0.4	5.5	13	38.7	15	3.7	100	76.3
Ahmwdabad (Solanki et al., 2014)	2014	39.5	2.2	5.7	7.3	27.2	15.6	2.7	100.2	60.7
Agra, Uttar Pradesh (Agarwal et al., 2015)	2015	39.96	5.2	10.3	7.2	22.7	12	2.6	99.96	60
Ballabgarh, Haryana (Gupta et al., 2015)	2015	46.8	3.1	3.3	3.1	18.2	24.8	0.7	100	53.2
Raipur, Chattisgarh (Boregowda et al., 2015)	2015	37.9	1	7.6	9.1	21.8	16	6.7	100.1	62.2

Mumbai, Maharastra (Savanur and Ghugre, 2015)	2015	52.2	2.6	7.5	8.2	16.1	9.4	3.7	99.7	47.5
Kolkata, West Bengal (Sarkar et al., 2015)	2015	52.7	2.2	12.1	3.3	17.6	6.6	5.5	100	47.3
Jammu, India (Dewan et al., 2015)	2016	26.8	6.4	8.4	6.8	9.2	26.4	16	100	73.2
Nagpur, Central India (Dhok and Thakre, 2016)	2016	41.41	2.73	8.2	4.3	19.92	10.55	12.89	100	58.59
Odisha (Goswami, 2016)	2016	45.5	5.1	7.4	16.2	15.4	5.1	5.2	99.9	54.4
Bengalore, India (Keri et al., 2016)	2016	48.15	4.94	3.7	6.17	24.69	9.87	2.47	99.99	51.84
Delhi (Gupta et al., 2017)	2017	38	8	11	6	17	19	1	100	62
Ahmedabad (Rastogi et al., 2017)	2017	21.48	13.22	4.13	16	22.31	10	3	90.14	68.66
Kottayam, Kerala (Jayalakshmi and Jissa, 2017)	2017	54.3	6.5	18	6.2	6.8	0.3	7.8	99.9	45.6
Hooghly, West Bengal (Manjula et al., 2017)	2017	52.5	11.5	7.1	8.8	7.1	11.5	1.6	100.1	47.6
Delhi, India (Daral et al., 2017)	2017	42.5	4.4	11.2	8.7	17.5	14.6	1.5	100.4	57.9
KarbiAnglong, Assam (Kramsapi et al., 2018)	2018	49	9.25	5	4.25	16.25	15	1.25	100	51
South 24 Pargana, West Bengal (Biswas et al., 2018)	2018	38.7	5	22.1	8.2	12.8	5.2	7.9	99.9	61.2
Visakhapatnam,Andhra Pradesh (Namburi and Seepana, 2018)	2018	44	6	8	8	15	13	6	100	56
Pune, Maharastra (Rasheed and Jeyakumar, 2018)	2018	24.7	0	10.8	30.8	15.8	7.2	10.6	99.9	75.2
Narpur, India (Kherde et al., 2018)	2018	48.91	10.43	12.17	2.61	8.48	11.52	5.87	99.99	51.08
Bankura, West Bengal (Patsa and Banerjee , 2018)	2018	59.3	3.49	6.98	3.49	10.47	8.14	8.14	100.01	40.71
Lakhimpur, Assam (Bharali et al.,2019)	2019	51.4	4.7	4.9	1.9	13.3	20.9	2.8	99.9	48.62
Tiruchirappalli, Tamil Nadu, India (Prabhakar et al., 2019)	2019	15.0	4.0	9.0	36.0	17.0	19.0	0.0	100	85.00