An Intersectional Analysis of the Composite Index of Anthropometric Failures in India

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Research

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Abstract

Background: Nutritional inequality in India has been estimated typically using stunting, wasting and underweight separately which hide the overall magnitude and severity of undernutrition. We used the Composite Index of Anthropometric Failure (CIAF) that combines all three forms of anthropometric failures to assess the severity of undernutrition and identify the most vulnerable social groups and geographical hotspots.

Method: CIAF was constructed using child anthropometric data from the fourth round of the National Family Health Survey (NFHS-4, 2015-16). We considered 24 intersecting sub-groups based on intersections across four main axes of inequality i.e., caste [Scheduled Tribe (ST), Scheduled Caste (SC) and Other], economic position (poor and non-poor), place of residence (rural and urban) and gender (male and female) (eg. ST-Poor-Rural-Female). Cross-tabulation and logistic regression were done to assess the odds of CIAF among intersecting groups and to identify the most vulnerable sub-groups. Concentration curve was plotted to visualise economic inequality in child undernutrition across caste categories. Choropleth maps were constructed and descriptive analysis of the district-level prevalence of CIAF was performed to identify the geographic clustering of undernutrition.

Results: Overall 55.1% of children were undernourished by CIAF and 6.7% of children have simultaneous three anthropometric failure. In sub-group analysis, children from ST and SC caste have a higher risk of undernutrition irrespective of other axis of inequality. The typical urban advantage is reversed among the children from poor SC and other-caste in most sub-groups. Compared with CIAF, socio-economic inequality was amplified for simultaneous-three-failures among all caste categories. Socio-economic inequalities within caste are more for other caste and SC categories than with ST. Based on the analysis of the high prevalence in the co-occurrence of two or three failures, 111 districts from 12 of 29 states in India were identified across four geographic clusters.

Conclusions:

The study shows social and eco-geographical clustering of multi-dimensional anthropometric failures and indicates the need for focused nutritional interventions among SC and ST community in general and ST children from the poor households. Furthermore, governance interventions that target entire regions across districts and states combined with decentralised planning are needed.

Background

India with 46.6 million children stunted and 25.5 million children wasted contributes to the highest global burden of undernutrition (1). In terms of prevalence, India has the second-highest prevalence of underweight (35.7%) next to Eritrea (38.8%) and third-highest prevalence of wasting (21%) only after South Sudan (22.7%) and Djibouti (21.5%) (2). While India bears the highest global burden of child undernutrition, the burden of child undernutrition in India is disproportionately distributed across social groups, economic position, religion, geographical area and gender (3,4). Inequality in undernutrition perpetuates other forms of inequality and contributes to intergenerational disadvantage, because of its influence on reduced mental and physical capabilities, and increased risk of morbidities and mortality that reduce the life chances of individuals, hence nutritional inequality is an important public health problem. Nutritional inequalities in India are already well characterised across caste (5,6), economic position (7,8), gender (9), and place of residence (10) by single axis. The single-axis analysis of nutritional inequalities, while providing important information on gradients along these axes, does not tell us how undernutrition is distributed within intersecting social groups. For instance, caste by economic position or by place of residence characterisation of these inequalities is unavailable. Indeed, a growing body of work on intersectional theoretical perspective and approach in health inequality research recognises multiple interacting axes of health inequalities such as caste, class, gender, disability, migration status etc often perversely accumulating in particular intersectional sub-groups (3,11–14). The interaction of the multiple identities such as caste, economic position, gender and place of residence produces a complex and diverse pattern of health outcomes (12). Several studies have reported that the burden of child
undernutrition in India is disproportionately distributed across the multiple axes of social power such as caste, class, religion, and gender (3,7,9). Though intersectional analysis of nutritional inequality by caste, economic position, gender and place of residence (3,9,11) and spatial inequality by inter and intra-district inequalities among 640 Indian districts are available (15–18) these analyses have been conducted using anthropometric measures of failure (stunting, wasting and underweight) separately and do not provide a comprehensive estimate of nutritional inequality in India.

While stunting indicates chronic undernutrition, wasting indicates acute undernutrition and underweight is the composite measure of both stunting and wasting (19–21). According to WHO these three indices reflect distinct biological conditions and any single index cannot be a proxy for these distinct biological phenomena (21). While categories of under-nutrition based on one of the three indices are helpful diagnostic parameter, a population-level comprehensive estimate of anthropometric failure was needed to account for all population-level co-occurrence of undernutrition (20). The Composite Index of Anthropometric Failure (CIAF) was developed by Svedberg (2000) as an aggregated indicator of stunting, wasting and underweight (22). The initial model developed by Svedberg had six subgroups of anthropometric failures (A-F) namely; A- no failure, B- only wasted, C- underweight and wasted, D- stunted, wasted and underweight, E- stunted and underweight, F- only stunted. To these six subgroups, Nandy et al added one more sub-group Y- only underweight (23). The CIAF includes the subgroups B-Y and excludes group A with no failure. While it provides an overall magnitude of undernutrition in a population more comprehensively, it also measures the severity of undernutrition by identifying children with multiple anthropometric failures that form the priority group for policy-makers (19,22,23). The Meta-analysis of effects of malnutrition in low-and-middle-income countries shows that children with all three failures have the highest risk of mortality (HR= 12.3, 95% CI= 95% CI: 7.7 - 19.6) among the undernourished children, combination of two failures, wasted and underweighted was reported more hazardous (HR: 4.7; 95% CI: 3.1,7.1) than being stunted and underweight (HR: 3.4;95% CI: 2.6, 4.3) (24). Hence, from policy and program perspective, CIAF index is an effective instrument for identifying the nutritionally most deprived groups given higher risk of mortality in individuals and populations with co-occurring nutritional failures.

While CIAF reveals the intersections of multiple anthropometric failures, an analysis of CIAF across intersectional sub-groups of caste, economic position, gender and place of residence helps us to identify the most vulnerable social sub-groups with severe forms of undernutrition. Further to this, given the heterogeneous nature of Indian districts in terms of dietary pattern, social norms and socio-economic inequality, identifying the districts with the highest burden of undernutrition will improve equitable policy formulation and interventions. India’s flagship nutritional program, POSHAN Abhiyaan considers the district as an important sub-unit for action, and district level monitoring is a key element in its implementation. Unlike the previous round of National Family Health Survey (NFHS), the most recent NFHS-4 (2015-16) survey collected unites of samples from district level that enables fine-scale characterisation of undernutrition analysis at the district level. Identification of high-priority districts based on CIAF and intersectional analysis across social groups hold the potential for more comprehensive identification of the high-priority districts and regions. This could also guide targeted and context-specific nutritional interventions and to improve precise financial allocations to the high-priority districts.

Methods

The data from the fourth round of the National Family Health Survey (NFHS 4, 2015-16) was used to assess the severity of under-nutrition among sub-groups. NFHS is a nationwide survey across a representative sample of households and follows the Demographic and Health Surveys (DHS) system in its use of standardised questionnaires, sample designs, and field procedures. There have been four rounds of NFHS; NFHS-1 (1992–93), NFHS-2(1998–99), NFHS-3 (2005–06) and NFHS-4 (2015-16). NFHS-4 collected information from a nationally representative sample of 601,509 households and interviewed 699,686 women (age 15–49), and 112,122 men (age 15– 54) living in all the 29 states of India. Anthropometric data were collected for 259,627 children who stayed in the household the night before the interview. Survey data was collected during the year 2015-16. The survey has calculated height/age, weight/age, weight/height standard deviation based on the new WHO growth chart (25). Children below -200 height/age, weight/age, and weight/height standard deviation is categorised as
stunted, underweight and wasted respectively. CIAF was constructed using child anthropometric data from National Family Health Survey (NFHS 4, 2015-16).

Concentration curve (cc) was plotted to visualise the pattern and magnitude of economic inequality in child undernutrition within each caste category. The cumulative percentage of CIAF is plotted on the y-axis and cumulative percentage of wealth status ranked by wealth index on the x-axis. If the concentration curve lies above the 45° line (the line of equality), it means inequality against the poor and if the curve lies below the line of equality it means the inequality against the rich exist. If the curve is a straight line equal to the line of equality, it depicts perfect equality in child undernutrition irrespective of wealth status and associated concentration index. In order to identify geographical clustering of CIAF, choropleth maps were constructed using GeoDa and descriptive analysis of the district-level prevalence of CIAF was performed. In simultaneous three failures and two failures, we categorised the district as high, medium and low prevalence based on the mean and standard deviation of the district-wise prevalence in each category. The district with a high prevalence of all three failures, simultaneous two failures of wasting and underweight, underweight and stunting were categorised as critical districts for urgent policy interventions. Similarly, high prevalence district in all three failures and either one of the two-dimensional failures were categorised as very serious and high prevalence of two of the two-dimensional failures or only all three failures were categorised as serious districts.

In order to understand the impact of intersecting categories on the nutritional status of children by CIAF, the study followed the intersectional categorisation of Indian social groups by Sen et al (2009). For some axes that had multiple sub-categories, these were aggregated/dichotomised. For instance, wealth quintiles were recoded into poor and non-poor; poorest and poorer categories were combined into a single category “poor”, and the middle, rich and richest wealth quintiles were grouped into “non-poor”. In the case of caste, SC and ST were coded separately while OBC and other caste were grouped as Other. Wherever responses for caste were missing (3.4%; 9,214 cases) or reported as “don’t know”(0.9%; 1,832 cases), these were excluded (4.3% of the total sample) yielding a final sample size of 206,276. From these re-coded categories, twenty-four intersecting sub-groups were created and the prevalence of CIAF for each sub-group calculated (see Table 1). The unadjusted odds ratio of CIAF among each of these intersectional groups were calculated using logistic regression keeping Other-Non-Poor-Urban-Male as the reference category. The odds ratio for each intersectional sub-group were plotted using the ggplot2 package of R statistical software (26).

**Results**

**Types of anthropometric failures among children**

An overall CIAF prevalence of 55.1% among children was found as opposed to 38.4% (stunting), 35.7% (underweight) and 21% (wasting) in the NFHS-4 report. Among the CIAF categories, 22.4% of children suffer from only one form of anthropometric failure (groups B, F and G), whereas 26.6% of children have simultaneous two failures (groups C and E) and 6.7% have all three forms of anthropometric failures. Simultaneous two failures of stunting and underweight (18.5%; group E) is the highest reported type of anthropometric failure. Overall, children of ST Poor appear disadvantaged both in rural and urban areas; ST Poor Male Rural children have the highest proportion of simultaneous three forms of anthropometric failures (12.6%), whereas the ST Poor Male urban children have the highest proportion of children undernourished (71.5%). Both cross-tabulation of CIAF with wealth quintiles and the intersectional analysis shows that economic position is an important factor affecting the nutritional status of children measured by CIAF. There is a large difference in CIAF between children from the poor and non-poor economic position with non-poor advantage irrespective of gender, caste, and place of residences.

**Table 1: Descriptive table on the distribution of CIAF by intersecting sub-groups of Caste, Economic position, Gender and Place of Residence**

**Rural v/s urban inequality**
The cross-tabulation of urban-rural difference in CIAF shows 58% of children from the rural residence are undernourished by CIAF as against 48.3% of children in urban residences ($X^2=1649.002, p=.0001$). Similarly, while 6.78% of children have simultaneous three failures in rural areas, it is 4.93% in urban areas ($X^2=235.19, p=.0001$). However, the urban advantage is not uniformly distributed among all the social groups. While the urban nutritional advantage is observed more consistently among the ST children in both CIAF and simultaneous three failures, the urban nutritional advantage is reversed among the SC and other caste children from the poor household in most of the cases. The general pattern observed is that while undernutrition among the ST community is clustered more among the rural areas irrespective of gender and economic position, among the SC and Other caste, the urban nutritional advantage is reversed more among the poor households (See Fig: 1).

Figure 1: Rural v/s Urban Intersectional Subgroup Comparison

Concentration curve (CC) (figure 2) shows consistently higher socio-economic inequality in the severe form of undernutrition (simultaneous three failures) than aggregate CIAF index across all caste groups, indicating relatively more unfair clustering of simultaneous three failures across caste groups than with CIAF. While the highest proportion of children from ST suffered simultaneous three failures, the same community reported the lowest rate of inequality in nutritional status by wealth quintiles. The lack of economic improvements among the ST community limits our ability to assess the role of socio-economic position in improving the child nutritional status among ST. In OBC and general category (other) where the spread of households across all socio-economic positions is seen, the rich-poor inequalities are higher (compare with ST). Interestingly, the CC of SC demonstrated a shifting trend; while the poorest wealth quintile, of both SC and ST groups, coincide, higher up on the socioeconomic gradient, the SC group makes a departure from this trend and shows increasing inequality and coincides with OBC and general categories. This means that the nature of inequality in child nutritional status among the SC poorest wealth quintiles is similar to that of the ST community whereas, among the upper wealth quintiles the inequality increases further indicating differential effects of socio-economic improvements within the SC category.

Figure 2: Concentration Curve for CIAF by Caste Category

Based on >1 SD of the mean district prevalence of co-occurring two failures or simultaneous all-three-failures, (>23% for stunting and underweight, > 11.7% wasting and underweight, >9.5% all-three-failures; see supplementary file 1), critical (11), very serious (72) and seriously affected (28) districts were identified. In all the critical districts, nearly half (>45%) of children reported at least two simultaneous anthropometric failures. Among these, the dangs district from Gujarat reported the highest proportion (60.1%) of children with at least two failures. From the states of Bihar and Jharkhand two districts each and from Chhattisgarh, Karnataka, Madhya Pradesh, Rajasthan, Uttar Pradesh, and West Bengal one district each was reported as critical (see supplementary file 2). Among the very serious districts, Pashchimi Singhbhum district in Jharkhand with 64.7% of children with at least two anthropometric failures nearly met the criteria for being a critical district (underweight and wasting prevalence 11.5%; all-three-failures 21.2%; and stunting and underweight 32%). The highest number of very serious districts are reported from Madhya Pradesh (19), followed by Jharkhand (13) (see supplementary file 3 for details). Gujarat has the highest number of serious districts (8) followed by Odisha (4). Overall spatial distribution of critical, very serious and serious district-level prevalence shows geographical clustering of these districts in four undernutrition hotspots spanning over 12 high burden states. In south India, a cluster of eight districts in north Karnataka forms the undernutrition hotspot. The second undernutrition hotspot is eleven districts along the state boundaries of Chhattisgarh (4), Odisha (6) and Maharashtra (1). The third hotspot is spread across the regions spanning the borders between West Bengal, Bihar and Jharkhand consisting of 28 districts, of which 11 are from Bihar, 3 from West Bengal and 14 from Jharkhand. The fourth hotspot is 53 districts spanning across Madhya Pradesh (23), Rajasthan (7), Gujarat (17), Maharashtra (4) and Uttar Pradesh (2) (See figure 3).

Figure 3: Undernutrition hotspots in India

**Critical districts** = High prevalence in all three failures, stunting and underweight, and underweight and wasting.
Very serious districts = High prevalence in all three failures, stunting and underweight or underweight and wasting.

Serious districts = High prevalence in all three failures or high prevalence in stunting and underweight, and underweight and wasting.

The Moran plot shows a linear fit through the point cloud. The slope of this line corresponds to Local Moran’s I values were 0.615 for stunting, wasting and underweight, 0.69 for stunting and Underweight, and 0.63 for wasting and underweight. All the coefficients were statistically significant (see figure 4). This indicates that the three-dimensional and two-dimensional anthropometric failures among children in India is not uniformly distributed across Indian districts, rather there is significant clustering of the high prevalence of two-dimensional and three-dimensional failures in India, further strengthening the case for identifying hotspots.

Figure 4: Univariate LISA maps of India showing clustering of undernutrition hotspot and cold spot by two dimensional and three-dimensional anthropometric failures

Discussion

The novelty of this paper is in its use of CIAF with intersectional analysis to identify sub-groups with the highest overall prevalence and severity of undernutrition and simultaneous anthropometric failures. The clustering of undernutrition across CIAF-based hotspots of two dimensional and three-dimensional anthropometric failures confirms the need for strategies that target larger geographical regions across districts and states.

Previous studies have identified undernutrition hotspot districts for high priority action based three measures of undernutrition separately (stunting, wasting and underweight) (15–18). Overall, 225 districts have been identified as hotspots based on the high prevalence of three indicators assessed separately (15). Our study, by applying comprehensive measures of undernutrition and assessing co-occurring failures, identified 111 districts that appeared to be most in need of action. Within in these 111 districts, we have further categorised critical, very serious and seriously affected districts based on the urgency of action. The districts we identify possibly have higher disadvantages due to the clustering of multiple failures. Interestingly, six districts identified as serious (Mahesana and Amreli in Gujarat, Ratlam, Harda, and Shahdol in Madhya Pradesh, and Bankura West Bengal) were not among the undernutrition hotspots identified in previous studies. All the critical and very seriously affected districts in our study have been identified in the single-axis analysis (15).

The clustering of critical, very serious and seriously affected districts also indicates the eco-geographical dimension to the phenomenon of undernutrition. The undernutrition hotspots identified in this study are mostly clustered in the climatic zones of hot and dry (with 40–45°C during summer days) and composite climatic zones (with 32 – 43°C during summer days) (27). The hot and semi-arid climate is also associated with crops cultivation (millets) and other social factors thus requiring interdisciplinary approaches to identify drivers of such clustering (28). Although hotspot identification is helpful for national-level priority setting, there are several districts in better-off states which continue to have vulnerable groups and undernutrition pockets within districts. For example, in the well-performing state of Kerala, the nutritional status among ST communities is better than the national average of ST communities based on NFHS 4 (2015-16) survey. However, there are the tribal population with a very high prevalence of undernutrition that reported 82.9%, 83.6%, and 82% of stunting, underweight and wasting among respectively that requires urgent policy attention (Gangadharan, 2011).

The usual urban advantage observed at national level aggregated data is not uniformly distributed among all social groups. While the urban advantage is consistently observed among the ST community with an exception for ST urban poor male in all three failures, it is reversed among most of the urban poor from SC and other castes. Rapid urbanisation combined with rural to urban migrations largely of the rural poor has been associated with increasing inequalities in Indian cities (31). Increased clustering of urban poor in slums characterized by limited access to public health and nutrition services and amenities (32,33) along with other known risk factors for undernutrition such as a high density of population, poor quality drinking water, inadequate sanitation facilities, and unhygienic conditions could be the plausible explanation for diminishing
the apparent urban advantage disproportionately for the poor among SC and other castes. Further, urban poverty too is not uniformly distributed across states; there is a high concentration of urban poor in the poorer states in central and north India, possibly contributing to the greater hotspots in these states (34). Inter-state and regional variations in urban migration and rural-urban inequalities in child undernutrition in India may reveal different regional patterns. Previous studies have reported a higher rate of poverty among the ST community compared with all other caste groups (35) and the ownership of household assets and amenities were lowest among ST community particularly the access to an improved source of drinking water, improved toilet facility, ownership of a pucca house which are important determinants of child nutrition (36–38). In connection with this, the lowest socio-economic inequality in child nutritional status among the ST group as shown in the CC indicates that the lack of economic improvements among ST community limits our understanding about the role of socio-economic position in improving the child nutritional status among ST community. Shifting CC in all three failures for SC community seems to suggest better social mobility in the SC community compared with the ST community. Consistent with these previous studies reported that although both SC and ST communities are disadvantaged, SC data indicates higher mobility in income, education, employment status, and political representation (38,39).

**Conclusion**

Overall the study shows social and eco-geographical clustering of multi-dimensional anthropometric failures and indicates the need for focused nutritional intervention for SC and ST community in general and ST children from the poor economic position and decentralised planning in nutritional intervention considering socio-demographic and ecological factors. The intersectional analysis of CIAF is useful in bringing out the multiple dimensions of child nutritional inequality. On one hand, while the CIAF provides biological gradients of severity in undernutrition, the intersectional analysis brings out the multiple dimensions of social identities that underlie the severity of undernutrition. The groups that are disadvantaged on several dimensions such as poor from SC and ST communities in rural residence need more priority attention. Clustering of critical, very serious and serious districts into undernutrition hotspots suggest the prioritisation of malnutrition hotspots for the nutritional interventions and more decentralised planning considering the eco-geographical factors. The finding also cautions against the policy formulation and programme implementation based on the single axis of inequality. Further investigation of intra_district and state variation in socio-economic inequality in child nutritional status among the caste groups is warranted to design district-specific interventions that can improve equity in child nutritional outcomes.

**Abbreviations**

CIAF: Composite Index of Anthropometric Failure; NFHS: National Family Health Survey; ST: Scheduled Tribe; SC: Scheduled Caste; OBC: Other Backward Caste; DHS: Demographic and Health Surveys; WHO: World Health Organisation; CC: Concentration Curve.

**Declarations**

**Ethics approval and consent to participate**

Our study is based on the National Family Health Survey, 2015–16 for India with no access to personal identifiers. This dataset is available in the public domain for research use and hence no approval was required from any institutional review board.

**Consent for Publication**

Not applicable

**Availability of data and materials**
The data can be downloaded from the website of the Demographic and Health Survey (DHS) (https://dhsprogram.com/data/). The data for the current study were downloaded from the afore-mentioned website.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

Sabu K U conceptualised, designed, analysed data and prepared the first draft and finalised manuscript of the study; Yogish Channa Basappa analysed the district level data and reviewed the first draft; Sangeetha V Joice compiled the data, conducted the literature search and prepared literature review; Prashanth Nuggehalli Srinivas participated in the design of the study, analysed data, and provided overall supervision in review and writing. All the authors reviewed and approved the final version.

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Tables
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<th>Intersecting Subgroups</th>
<th>N</th>
<th>%</th>
<th>Only wasting</th>
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**Note:** Table should appear inline number

**Figures**
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<th>A) Univariate LISA map of stunting, wasting and Underweight</th>
<th>B) Moran scatter plot of stunting, wasting and Underweight</th>
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<th>F) Moran scatter plot of wasting and Underweight</th>
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<td><img src="image6.png" alt="Moran Scatter Plot" /></td>
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Figure 1

Univariate LISA maps of India showing clustering of undernutrition hotspot and cold spot by two dimensional and three-dimensional anthropometric failures

Figure 2

Undernutrition hotspots in India
Figure 3

Concentration Curve for CIAF by Caste Category
Figure 4

Rural v/s Urban Intersectional Subgroup Comparison

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1.docx