Title: Assessing inequalities and regional disparities in child nutrition outcomes in India using MANUSH – a more sensitive yardstick

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Abstract

**Background:** India is strongly committed to reducing the burden of child malnutrition, which has remained a persistent issue. Findings from recent surveys indicate co-existence of child undernutrition, micronutrient deficiency and overweight/obesity, i.e. the triple burden of malnutrition in children below five years. While considerable efforts are being made to address this challenging issue, and several composite indices are being explored to inform policy actions, the methodology used for creating such indices, i.e., linear averaging, has its limitations. Briefly put, it could mask the uneven improvement across different indicators by discounting the ‘lagging’ indicators, signifying negative implications on policy discourse for improved nutrition. To address this gap, we attempt to develop a composite index for estimating the triple burden of malnutrition in India, using a more sensitive measure, MANUSH.

**Methodology:** Data from publicly available nation-wide surveys - National Family Health Survey (NFHS) and Comprehensive National Nutrition Survey (CNNS), was used for this study. First, we addressed the robustness of MANUSH method of composite indexing over conventional aggregation methods. Second, using MANUSH scores, we assessed the triple burden of malnutrition at the subnational level over different periods NHFS-3(2005-06), NFHS-4 (2015-16) and CNNS (2106-18). Through the use of maps and spatial tools, we gauged the existence of neighbourhood dependency, the formation of clusters, within and across states.

**Result:** MANUSH method succeeds over its counterparts – linear aggregation and geometric mean, by fulfilling additional conditions of Shortfall and Hiatus Sensitivity, implicitly penalising when, improvement in worst-off dimension is less or not proportionate to improvement in best-off dimension, or when, even with overall improvement, the gap between dimensions remain same. MANUSH scores helped in revealing the changing paradigm in the improvement of nutrition outcomes and the rising inequalities within and across states and districts in India. Significant clusters (p<0.05) of high burden and low burden districts were found, revealing geographical heterogeneities and sharp regional disparities. The usefulness of MANUSH index in context-specific planning and prioritising actions is also brought out using the case of the National Nutrition Mission.

**Conclusion:** MANUSH indexing depicts balanced development effectively, hence finds relevance in bringing out inequality in a diverse and developing economy like India.
Key words:

Composite index, Triple burden, Malnutrition, Balanced development, Spatial heterogeneity, Shortfall sensitivity, Hiatus sensitivity, Policy, India
1. Background

United Nations' Sustainable Development Goals 2 and Goal 3 reaffirm that proper nutrition is central to well-being of all individuals [1]. Malnutrition, if left unattended in the early age of a child, results in an irreversible effect on the cognitive and physical development of an individual hindering the overall development of human capital and economic growth [2]. Malnutrition contributes to nearly 68.2 per cent of deaths in children under five years of age in every state of India in 2017 [3]. The undernourished population is more vulnerable to infections and diseases in childhood and non-communicable diseases in adulthood [4].

Recent findings from both National Family Health Survey -4, 2015-16 (NFHS-4) [5] and Comprehensive National Nutrition Survey (CNNS), 2016-18 [6] confirm that India is grappling with triple burden of malnutrition among children under the age of five – undernutrition, and micronutrient deficiencies among many and emerging overweight/obesity in some. With explicit cognizance of the alarming scenario, nutrition has eventually taken centre stage of development agenda, in recent times, in India. A National Nutrition Strategy was formulated in the year 2017, through the consultative process by NITI Aayog, the think tank body of Government of India. The strategy caters to the problem of child and maternal malnutrition in India through focussed planning and convergent approach [7]. In March 2018, the Prime Minister of India launched the National Nutrition Mission (NNM), from Jhunjhunu district of Rajasthan. The Mission, also known as POSHAN Abhiyaan, aims to bring focus and momentum to the efforts to reduce child and maternal malnutrition as an overarching goal. The Abhiyaan or the campaign mode has been adopted to create a nationwide societal movement for improved national outcomes through convergent action at state and district level. The Abhiyaan rolled out in all districts across the country in a phased manner in three years (2017-20), i.e. 315 districts in the first year (2017-18), 235 districts in the second year (2018-19) and remaining districts to be covered in the third year (2019-20) [8].
The government of India has set the following targets to be achieved by the year 2022, in order to achieve 12 out of 17 United Nations’ Sustainable Development Goals related to nutrition by the year 2030:

- To prevent and reduce stunting and underweight in children (0-6 years) by 6% respectively, i.e. 2% reduction per annum
- To reduce the prevalence of anaemia among young children (6-59 months), women and adolescent girls in the age group of 15-49 years by 9%, i.e. 3% reduction per annum
- Reduce Low Birth Weight (LBW). By 6% @ 2% p.a.

It may be noted here that the problem of wasting and overweight/obesity has not been accorded priority even though its emergence needs to be recognised and tackled early [3].

To measure and monitor the progress made at the national and sub-national, efforts are being made to establish robust indicators, analytical tools and methodologies, to provide a clearer picture of the persisting problem of malnutrition – which in itself is multidimensional and complex and in nature. This is evident from a recent upsurge in the number of such indices to assess levels of development in different fronts in India. Examples include NITI Aayog’s Health Index [9], SDG index [10], Food and Nutrition Security Analysis [11]. These efforts in India are by and large a reflection of the global discourse that has witnessed the development of similar indices to assess levels of malnutrition, hunger and food insecurity across different countries. These indexes aim to serve as a tool for policymakers and various stakeholders to provide information on the world’s 'state of art' information on nutrition and health. Examples include Global Hunger Index (GHI) [12], the State of Food Security and Nutrition in the World 2019 [13], Poverty and Hunger Index (PHI) [14], the Hunger FREE Scorecard index [15], the Global Food Security Index [16] and Food Sustainability Index [17], among others.
Use of such indices is critical especially in a country like India, as they can bring out the non-uniform nature of development and inequalities due to huge disparities and heterogeneities existing across and within different regions at the national and sub-national level. Therefore, the selection of indicators, data quality, and method of aggregation used to create such composite indices become essential [18]. While there is an abundance of debate on the choice of indicators and data quality in the received literature, there are limited studies that focus on the selection of appropriate aggregation methods in creating composite indexes [19], which is very crucial and must be given special attention as elaborated in this analysis.

Several aggregation methods have been proposed in the literature, all with their advantages and drawbacks, and specific assumptions and properties. Linear aggregation method is the most common among these, extensively used in all the recent development indexes in India mentioned earlier in this paper. A problematic feature of this method is the masking effect due to the full substitutability among its components; higher values of some components can compensate for lower values of other components [19, 20]. Even Human Development Index (HDI), prior to 2010, was computed using linear aggregation method. It was noted for instance, that a weaker state of health in a particular country, could get masked in the aggregation by, say improved income levels. Suitability of the linear aggregation method was as such debated and criticised by several researchers for being inappropriate and from 2010 onwards, HDI is being computed using Geometric Mean approach [21, 22]. However, the geometric mean method too suffers from certain flaws and is inadequate on individual accounts, as noted by various researchers, including Mishra & Nathan (2018) [23].

Mishra & Nathan (2018) have proposed a set of six conditions that a composite measure should satisfy – Monotonicity, Anonymity, Normalisation, Uniformity, Shortfall Sensitivity and Hiatus Sensitivity. The abbreviated set also referred to as 'MANUSH', addresses inequality among individuals or subgroups within each dimension, as well as inequality between and
within different dimensions. Both the linear and geometric means satisfy the first three of these conditions viz — Monotonicity, Anonymity and Normalization. The geometric mean also satisfies an additional condition viz. Uniformity. The MANUSH method satisfies, in addition, the other two requirements. The Shortfall sensitivity requires that the worse-off to better-off dimensions should be at least in proportion to their shortfalls. The Hiatus sensitivity requires that the higher overall attainment (where nature of indicator used is positive) or greater overall reduction (where nature of indicator used is negative) must simultaneously lead to a reduction in the gap across dimensions. As we see below, there is an $\alpha$ measure which has to be $\alpha \geq 2$, and for MANUSH measure in this paper, the value of $\alpha=2$, termed as a displaced ideal method [23], will be mainly used.

Thus, this paper, intents to estimate the triple burden of malnutrition across 640 districts in India, by applying MANUSH measure on NFHS-4 data for these districts using indicators for undernutrition (Stunting and Wasting), micronutrient deficiency (anaemia) and overweight/obesity in children under the age of five. In the process, we first provide detail on how MANUSH measure outruns conventional aggregation methods – linear aggregation and geometric mean, by fulfilling additional conditions of Shortfall and Hiatus Sensitivity. Second, using mapping, we project how MANUSH method is more efficient in revealing inequalities at the national and subnational level, i.e. within and across states in India. Third, we discuss the policy implications, if MANUSH approach is adopted to create indexes, to support actions taken by policymakers, in order to combat malnutrition in India.

It is also important to point out here that a composite index for estimating the triple burden of malnutrition across 36 States/UTs and 640 districts in India using MANUSH approach has never been reported in the received literature so far. Moreover, since the focus of our study is on aggregating failure indicators; i.e. the lower the value, the better, and not attainment indicator where the higher the value, the better, we modify the definitions for explaining
MANSUH axioms, since the definitions used by Mishra & Nathan (2018) are for attainment indicators.

2. Methodology

Dimensions:

To compute the index for the triple burden of malnutrition – undernutrition, micronutrient deficiency and overweight/obesity, a total of four component indicators were used in this study. Two indicators, namely, % stunted children and % wasted children under the age of five, were selected as indicators to characterize undernutrition. As per World Health Organisation (WHO) [24], children are classified as ‘stunted’ who have low height for age z-score (below -2 standard deviation) and ‘wasted’ who have low weight for height z-score (below -2 standard deviation). Stunting and wasting represent chronic and acute forms of undernutrition, respectively. Percentage of children anaemic under the age of five was used as an indicator to describe micronutrient deficiency, especially that of iron. Overweight/ obesity was characterized by the percentage of children with weight for height z-score above +2 standard deviation.

Study Unit:

The composite scores and ranks were computed for both states and districts in India.

Data:

For states, scores were calculated using data compiled from factsheets of three different surveys respectively, namely, National Family Health Survey – 3 (2005-06) [25], National Family Health Survey-4 (2015-16) [26] and Comprehensive National Nutrition Survey (CNNS, 2016-18) [27]. For districts, scores were tabulated using data gathered from National Family Health Survey-4 (2015-16) [28], since it is the only survey, that provided district estimates for 640 districts in India, for the first time.
**Standardization:**

Values in all the four selected indicators – Stunting, Wasting, Anemia, Overweight/Obesity were first standardized using a threshold value as a denominator. This threshold value was set nearest to the maximum observed value in the survey data for that indicator; hence they were set differently for states and districts. The standardized value was calculated as,

\[ y_{ij} = \frac{V_{ij}}{T} \]

where, \( y \) represents standardized value for a given component indicator for a particular state or district; \( i \) indicates the indicator, \( j \) represents either state or district, \( V_{ij} \) represents the actual value of given component indicator for a particular state or district, and \( T \) represents Threshold value. The threshold value for stunting, wasting, anaemia and overweight/obesity was set at 60%, 40%, 85% and 10% respectively for states, and 70%, 50%, 95% and 20% respectively for calculating scores at the district level. Hence, the value of \( y_{ij} \) lied between 0 and 1. Lower the value of \( y_{ij} \), lower is the prevalence of stunted, wasted, anaemic or overweight/obese children under the age of five.

**Weights:**

Next step involved assigning of weights to each of these standardized indicators. For this study, we assigned same weights to the selected indicators as used by Swaminathan et al. (2019) for projecting prevalence of health-related Sustainable Development Goals (SDGs) indicators up to 2030 based on past trends in India. Since stunting, wasting, anaemia and overweight/obesity are all part of SDG indicators and also fall under the National Nutrition Mission (NNM) targets for the year 2022, we have used the same weights. Weights \( w_i \) of 1.7, 1.9, 1.0 and 1.7 respectively were assigned to standardized values of stunting, wasting, anaemia and overweight/obese respectively.
Calculation of Index:

After assigning weights, scores were computed for states and districts for estimating the triple burden of malnutrition using the three aggregation measures – MANUSH, linear aggregation and geometric mean. The MANUSH measure described by Mishra and Nathan (2018) was modified for this study, as the indicators used here were failure indicators and not attainment indicators. Hence the triple burden index using MANUSH measure was derived as follows:

\[
MANUSH_\alpha = \left[\frac{\sum_i \left(\frac{w_i y_{ij}}{w_i^\alpha}\right)}{\sum_i w_i^{\alpha}}\right]^{1/\alpha}
\] ………………………………………………………………………………………………………eq (2)

where \(\alpha = 1, 2, 3\ldots, \ldots, \infty\). The standardised higher values of \(\alpha\) take the attainment pathways closer to the ideal path, which ultimately approaches the line of equity as \(\alpha\) tends to infinity. In this paper, we have limited ourselves to the values of \(\alpha = 2\), which represents the displaced ideal method [23].

When \(\alpha = 1\), the index takes the form of linear aggregation (LA) and was thus derived as

\[
LA = \left[\frac{\sum_i \left(\frac{w_i y_{ij}}{w_i}\right)}{\sum_i w_i}\right]
\] ………………………………………………………………………………………………………eq (3)

On the other hand, the triple burden using the geometric mean (GM) method was computed as

\[
GM = 1 - \left[\prod_i (1 - y_{ij})^{(w_i)}\right]
\] ………………………………………………………………………………………………………eq (4)

The value of each of these computed index scores ranged between 0 and 1. Since these are failure indicators, lower the score, the closer is the state to achieving an ideal state. The ranking of states and districts in India was done using the computed scores (See Additional File 1).

Mapping for visualization:
To study the scenario of triple burden across states and districts in India based on MANUSH scores, maps were developed using QGIS version 3.4. We also conducted a spatial analysis using GeoDa version 1.14.0 to study spatial dependency across districts in India.

3. Results and Discussion

The resulted scores and ranks obtained by states and districts can be found in Additional File1.

3.1. Axioms Test

We first compared Linear aggregation and Geometric Mean method against MANUSH axioms, viz, Monotonicity, Anonymity, Normalization, Uniformity, Shortfall sensitivity and Hiatus sensitivity to level to bring out the differences in scoring patterns, if any, using districts as study unit. It will be seen that all the three aggregation measures (Linear aggregation, Geometric Mean and MANUSH) satisfy the first three axioms while differences appear in compliance with the rest three.

It is also to be noted that in the examples presented below, we have limited the values of individual indicators up to two decimals (except in case of normalisation axiom and shortfall sensitivity where these are limited to one and three decimal points respectively) to help in explaining our axioms, but cases may differ if we take the values to the third and subsequent decimal points. Hence, the caveat.

**Monotonicity.** A measure of aggregation (LA, GM or MANUSH) should be such that a decrease (increase) in failure in any one of the dimensions, other dimensions remaining constant, will lead to a decrease (increase) in the value of LA, GM or MANUSH.
For instance, given weighted standardized values of stunting, anaemia and overweight/obese being constant if standardized value of wasting is 0.13 in one district (case #1: example, Kaimur (Bhabua) in Bihar) and 0.09 in another (case #2: example, Vaishali in Bihar) then aggregation measure in case #1 should be greater than case #2.

Table 1: Cases explaining Monotonicity axiom

| Case | District | State       | Weighted Standardized values | Aggregation Scores |
|------|----------|-------------|-----------------------------|-------------------|
|      |          |             | wyst | wywa | wyan | wyow | GM  | LA  | MANUSH (α = 2) |
| #1   | Kaimur   | Bihar       | 0.21 | 0.13 | 0.11 | 0.01 | 0.53 | 0.45 | 0.52         |
| #2   | Vaishali | Bihar       | 0.21 | 0.09 | 0.11 | 0.01 | 0.51 | 0.42 | 0.49         |

We see from the above example that all the three indexing methods – linear, geometric and MANUSH satisfy the monotonicity condition. It is also to be noted that the geometric mean method will violate monotonicity if one of the dimensions has a value unity (1-unity being zero) and the other dimension keeps decreasing. Other instances where the condition of monotonicity is being fulfilled is presented in Additional File 1.

Anonymity. A measure of aggregation (LA, GM or MANUSH) should be invariant to the weight-adjusted interchange of failure level across dimensions.

For instance, given weighted standardized values of wasting and overweight/obese, if weighted standardized values of stunting and anaemia are 0.09 and 0.08, respectively, in case #1 and 0.08 and 0.09, respectively, in case #2 then value of aggregation measure in case #1 should be equal to value case #2, as seen in the case of Sangli district of Maharashtra and Sivaganga district of Tamil Nadu below.

Table 2: Cases explaining Anonymity axiom

| Case | District | State       | Weighted Standardized values | Aggregation Scores |
|------|----------|-------------|-----------------------------|-------------------|
|      |          |             | wyst | wywa | wyan | wyow | GM  | LA  | MANUSH (α = 2) |
| #1   | Sangli   | Maharashtra | 0.09 | 0.11 | 0.08 | 0.01 | 0.31 | 0.29 | 0.32         |
| #2   | Sivaganga| Tamil Nadu  | 0.08 | 0.11 | 0.09 | 0.01 | 0.31 | 0.29 | 0.32         |

All the three indexing methods - linear, geometric and MANUSH satisfy Anonymity condition.
Normalization. A measure of aggregation (LA, GM or MANUSH) should lie between zero and unity such that at zero all dimensions have no failure (the ideal situation, the value of aggregation measure = 0) and at unity, all dimensions have their maximum failure, the value of aggregation measure = 1).

| Case | District       | State            | Standardized values | Aggregation Scores |
|------|----------------|------------------|---------------------|--------------------|
|      |                |                  | y_{ST} y_{WA} y_{AN} y_{OW} | GM LA MANUSH (a = 2) |
| #1   | Lower Subansiri| Arunanchal Pradesh| 0.5 0.5 0.5 0.5 | 0.5 0.5 0.5 |
| #2   | Cuttack        | Odisha           | 0.2 0.2 0.2 0.2 | 0.2 0.2 0.2 |

All the three indexing measures - linear, geometric and MANUSH follow the condition of normalization as seen in the case above. It is implicit that if all dimensions have a common value then aggregation measure (LA, GM or MANUSH) will have that common value and if the common value is zero or unity, respectively then LA, GM or MANUSH will be zero or unity, depicting no failure or maximum failure respectively. Identifying the cases that explicitly satisfy the condition of normalization, was difficult in the present data set. However, reducing the decimal digits to one, we have identified few cases such as of Lower Subansiri district in Arunanchal Pradesh and Cuttack district in Odisha that prove the aforementioned axiom.

Uniformity. A measure of aggregation (LA, GM or MANUSH) should be such that for a given weighted-average of failure, a greater deviation across dimensions should give a greater aggregation value.

For instance, for a given weighted standardised values of stunting and anaemia, if weighted standardised values of wasting and overweight/obesity are 0.19 and 0.01, respectively, in case #1 (example, Dhar district in Madhya Pradesh) and 0.12 and 0.08, respectively, in case #2 (example, Karnal district in Haryana), then value of aggregation measures in case #1 should be greater than in case #2.
Table 4: Cases explaining Uniformity axiom

| Case | District | State     | wyst | wywa | wyAN | wyow | μ    | σ    | GM   | LA   | MANUSH (α = 2) |
|------|----------|-----------|------|------|------|------|------|------|------|------|---------------|
| #1   | Dhar     | Madhya Pradesh | 0.16 | 0.19 | 0.13 | 0.01 | 0.49 | 0.43 | 0.56 | 0.49 | 0.55         |
| #2   | Karnal   | Haryana   | 0.16 | 0.12 | 0.13 | 0.08 | 0.49 | 0.42 | 0.52 | 0.49 | 0.49         |

Here, it is also noted that only geometric mean and MANUSH method show change in their scores, thereby penalizing Dhar district for unbalanced development across a dimension of wasting and overweight, thus satisfying the condition of Uniformity. The linear aggregation method (LA), however, shows no change in its scores and does not penalise unbalanced development across dimensions.

Other instances where the condition of uniformity is being fulfilled is presented in Additional File 1.

**Shortfall Sensitivity.** A measure of aggregation (LA, GM or MANUSH) should be such that for a given reduction in the aggregation value along its optimal path between two situations the reduction across dimensions should be in proportion to the shortfalls in the worse-off dimensions.

If weighted standardized values in situation (#1) are such that wasting ($q_1$) is greater than stunting ($r_1$) which is greater than overweight/obesity ($s_1$) which is greater than anemia ($t_1$), or, $q_1 > r_1 > s_1 > t_1$, then, in situation (#2) the reduction in failures should be such that $(q_1 - q_2) \geq (q_1/r_1) (r_1 - r_2)$, $(r_1 - r_2) \geq (r_1/s_1) (s_1 - s_2)$, and $(s_1 - s_2) \geq (s_1/t_1) (t_1 - t_2)$. We see situation 1a (Upper Siang in Arunanchal Pradesh) and situation 1b (Kollam in Kerala) in Table 5 mimic the same order of indicators, where wasting represents the worse-off dimension and anaemia represents the best-off dimension. Kollam when compared to Upper Siang, shows a lower reduction, in the worse off dimension, i.e. in wasting, when compared to anaemia, it's best off dimension, and
hence is penalized by MANUSH measure ($\alpha \geq 2$). We even notice that when we increase $\alpha$ measure, that is $\alpha=3$, 5 and 10, Kollam is further penalized on account of disproportionate reduction in its best-off and worse-off dimension. Conversely, when we study the situation 2a and 2b in table below, of Dakshin Dinajpur of West Bengal and Kanniyakumari of Tamil Nadu, which follow the same order of indicator values, where, stunting represents the worse-off dimension, followed by anaemia, wasting and overweight/obesity, represents the best-off dimension, we see that Kanniyakumari when compared to Dakshin Dinajpur, shows more reduction in its worse-off dimension, i.e. stunting, in comparison to its better off dimensions, it is not penalized by MANUSH measure ($\alpha \geq 2$), on account of being sensitive to shortfall across its best-off and worse-off dimension.

Table 5: Cases explaining the condition of Shortfall Sensitivity

| Situation | District          | State             | $q = \frac{wy}{w}$ | $r = \frac{wy}{w}$ | $s = \frac{wy}{w}$ | $t = \frac{wy}{w}$ | $q-q_r$ | $r-t_r$ | $t-s_t$ | $s-s_o$ | $s-t_s$ | $t-t_o$ |
|-----------|------------------|-------------------|--------------------|--------------------|--------------------|--------------------|---------|---------|---------|---------|---------|---------|
| 1         | Upper Siang      | Arunanchal Pradesh| 0.18               | 0.09               | 0.08               | 0.07               | 0.06    | 0.07    | 0.04    | 0.03    | 0.03    | 0.05    |
|           |                   |                   |                    |                    |                    |                    |         |         |         |         |         |         |
|           | Kollam           | Kerala            | 0.11               | 0.06               | 0.05               | 0.03               |         |         |         |         |         |         |
| 2         | Dakshin Dinajpur | West Bengal       | 0.13               | 0.11               | 0.10               | 0.06               | 0.06    | 0.06    | 0.05    | 0.05    | 0.05    | 0.04    |
|           |                   |                   |                    |                    |                    |                    |         |         |         |         |         |         |
|           |                   |                   |                    |                    |                    |                    |         |         |         |         |         |         |

Table 5 continued

| Situation | District          | State             | GM | LA | MANUSH ($\alpha = 2$) | MANUSH ($\alpha = 3$) | MANUSH ($\alpha = 5$) | MANUSH ($\alpha = 10$) |
|-----------|------------------|-------------------|----|----|------------------------|------------------------|------------------------|------------------------|
| 1         | Upper Siang      | Arunanchal Pradesh| 0.439 | 0.426 | 0.447 | 0.470 | 0.510 | 0.559 |
|           |                   |                   |      |     |                        |                        |                        |                        |
|           |                   |                   |      |     |                        |                        |                        |                        |
|           |                   |                   |      |     |                        |                        |                        |                        |
|           |                   |                   |      |     |                        |                        |                        |                        |
|           |                   |                   |      |     |                        |                        |                        |                        |

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This indicates that neither geometric mean nor linear aggregation methods are shortfall sensitive. Few more cases that explain shortfall sensitivity, and are reported in Additional File 1.

**Hiatus Sensitivity to Level.** A measure of aggregation (LA, GM or MANUSH) should be such that the same gap (or hiatus) across dimensions should be considered worse-off as average failure decreases.

For instance, if standardized values of stunting, wasting, anaemia and overweight/obesity are 0.18, 0.17, 0.13 and 0.03, respectively, in case #1 and 0.17, 0.16, 0.12 and 0.02, respectively, in case #2, as observed in Surendranagar of Gujarat and Bhojpur of Bihar, which has the same gap across dimension, then value of aggregation in case #1, in comparison to case #2, should have a lower deviation from its average failure (µ). We see that except MANUSH aggregation method, neither linear aggregation nor geometric mean, has a lower deviation from the average failure, in case of Surendranagar. Hence, the gap in MANUSH score between the two districts, i.e. Surendranagar and Bhojpur, are found to be narrow, compared to the gap in linear and geometric mean scores between two districts. Hence MANUSH is also hiatus sensitive. What this condition means, in essence, is that the gap between different dimensions should continue to reduce as a district moves towards a greater reduction in failure.

| Case | Districts | State | wyST | wyWA | wyAN | wyOW | µ | GM | LA | MANUSH (α = 2) | GM - µ | LA - µ | MANUSH - µ |
|------|-----------|-------|------|------|------|------|---|----|----|----------------|-------|-------|-----------|
| #1   | Surendranagar | Gujarat | 0.18 | 0.17 | 0.13 | 0.03 | 0.50 | 0.56 | 0.50 | 0.54 | 0.06 | 0.00 | 0.04 |
| #2   | Bhojpur | Bihar | 0.17 | 0.16 | 0.12 | 0.02 | 0.46 | 0.51 | 0.46 | 0.51 | 0.05 | 0.00 | 0.05 |

As noted above, Linear aggregation method, satisfies the conditions of monotonicity, anonymity and normalization but fails to satisfy other three axioms and therefore does not penalizes unbalanced development across dimensions and is insensitive to shortfall and gap.
across dimension despite lower attainment in case of failure indicators (same is true when there
is higher attainment when indicators are positive in nature). On the other hand, the geometric
mean measure also satisfies the condition of Uniformity in addition to the axioms satisfied by
GHI, (exception for monotonicity, where any $y_{ij} = 0$) but does not satisfy shortfall and hiatus
sensitivity. However, MANUSH $\alpha$ measure $\geq 2$ satisfies two additional axioms – shortfall
sensitivity and hiatus sensitivity to level, which are important to in the context of any
development, and is extremely relevant in context to assessing the burden of malnutrition in a
country like India, with wide geographical heterogeneities. Due to the difference in satisfying
one or more axioms, we observe the difference in scores and thus in the ranking, using three
aggregation measure. From the above testing of axioms, it is thus evident, that MANUSH is a
more robust and sensitive approach for creating composite indexes.

We next highlight and discuss the implication of MANUSH indexing in assessing nutrition
burden across states and districts in India and in developing national policies on eradicating
malnutrition

3.2. Comparing the nutrition scenario in India at a different level of aggregation:

a) Nutrition scenario across State Boundaries in India:

Comparing the nutrition status in states of India over three different periods of surveys, i.e.
from NFHS-3 (2005-06) to NFHS-4 (2015-16) to CNNS (2016-18), we see a significant
upward shift at the state level. For the purpose of this study, states have been grouped into low
($<0.35$), moderate ($\geq 0.35$ and $<0.45$), serious ($\geq 0.45$ and $<0.55$), alarming ($\geq 0.55$ and $<0.65$)
and extremely alarming ($\geq 0.65$) category on a severity scale based on their respective
MANUSH scores, as seen in Figure 1a-c.
At the time of NFHS-3 (see Figure 1a), four states fell under extremely alarming category (MANUSH score ≥0.65), namely Madhya Pradesh (0.73), Meghalaya (0.72), Jharkhand (0.70) and Bihar (0.69) on account of extremely high prevalence of stunted and wasted children below the age of five. Seven states – Uttar Pradesh (0.61), Sikkim (0.61), Chhattisgarh (0.61), Gujarat (0.59), Haryana (0.56), Rajasthan (0.56) and Odisha (0.55) were found in the alarming category as per MANUSH scores. All the seven states but Sikkim were penalized for the high prevalence of stunting, whereas Sikkim was accounted for the high prevalence of both stunted and overweight/obese children. Only four states – Punjab (0.43), Goa (0.41), Manipur (0.39) and Kerala (0.36) were found in the moderate category with MANUSH score in the range of ≥0.35 and <0.45. Here we see that although Manipur fared better in all dimensions (weighted standardized score wasting 0.07, anaemia 0.08, overweight 0.06) except stunting (weighted standardized score 0.16), compared to Kerala (stunting 0.11, wasting 0.12, anaemia 0.08, overweight 0.03), yet Manipur was penalized on account of unbalanced development across its dimensions. None of the states was found to fall under low category (MANUSH score <0.35) and about 13 states were found to fall under the serious category (MANUSH score ≥0.45 and <0.55). We had to exclude Nagaland from NFHS-3 study as the anaemia prevalence was not known.

Figure 1: Map of India depicting state categorization on the severity scale based on MANUSH scores calculated based on a) NFHS-3 b) NFHS-4 c) CNNS

Next, we study the nutrition scenario across states in India after NFHS-4 round (See Figure 1b). It is important to note that third round of National Family Health Survey (NFHS) was conducted in all states of India, which were 28 in number, barring 6 Union Territories but Delhi. Andhra Pradesh was undivided State at the time of NFHS-3, which got divided into two
During NFHS-4, all 29 States along with 7 Union Territories were surveyed along with 640 districts.

On comparing the nutrition scenario in states surveyed in NFHS-4 with previous round, i.e. NFHS-3, it is found that none of the states falls in the extremely alarming category (MANUSH score $\geq 0.65$), except Dadra and Nagar Haveli (MANUSH Score 0.67), which is a Union Territory (UT) and have been penalized on performing poorly on all four dimensions. Three states, Jharkhand (0.64), Madhya Pradesh (0.59) and Bihar (0.58), when compared to NFHS-3, have shifted from extremely alarming to alarming category on account of reduction in stunting and wasting, although overweight/obesity shows marginal rise in children below five years in these states with no or minimal reduction in anaemia. Sikkim (0.60) and Gujarat (0.57) show no change in the category on the severity scale and are still found in the alarming category in NFHS-4 round. Although, Gujarat shows a reduction in stunting, but is penalized on account of increased prevalence of wasting. Sikkim also shows a reduction in stunting but is penalized on account of rise in both wasting and overweight/obesity in children under the age of five. On the other hand, Karnataka (0.56) shows a downward fall from serious to alarming category between NFHS-3 and NFHS-4. It is penalized on account of rise in prevalence of both wasting and anaemia, with no reduction in overweight/obesity in children below five years.

Meghalaya (0.52) shows a significant upward transition from extremely alarming to serious category between two rounds of the survey and has been duly rewarded on account of a significant reduction in wasting, followed by a reduction in stunting and anaemia, although it shows a rise in overweight/obesity in children under the age of five. Uttar Pradesh (0.54), Rajasthan (0.54), Haryana (0.53), Chhattisgarh (0.52) and Odisha (0.47) also show one -scale upward shift from alarming to the serious category in NFHS-4 on account of robust decline in stunting, followed by anaemia. Although, except Odisha, we see an increase in wasting in all
the four states. On the other hand, Goa (0.45) shows one-scale shift downwards, i.e. from moderate to serious category and has been penalized on account of an unprecedented rise in wasting and anaemia, despite a small reduction in stunting and children under five years. Maharashtra (0.53), Uttarakhand (0.50), Tamil Nadu (0.49), Arunanchal Pradesh (0.49), West Bengal (0.47) and Jammu and Kashmir (0.47), continue to be in serious category. Although, except Jammu and Kashmir, all the five states show a reduction in MANUSH scores, compared to NFHS-3. It is observed that Jammu and Kashmir, is penalized on account of a significant increase in the prevalence of overweight/obesity, despite the reduction in all the other three dimensions. Daman and Diu (0.50) and Puducherry (0.45), the union territories, are also found in serious category, with former penalized on account of a high prevalence of wasting and anaemia and later due to high prevalence of wasting with respect to other dimensions.

Assam (0.44), Delhi (0.44), Andhra Pradesh (0.44), Telangana (0.43), Tripura (0.40), Himachal Pradesh (0.38) and Mizoram (0.35) show a gradual shift from serious to moderate category. While Assam is rewarded for the decline in stunting and anaemia, Delhi shows a reduction in overweight/obese children followed by stunting. Tripura shows a reduction in all parameters but overweight, which is found to increase between the two rounds of the survey. Himachal Pradesh shows a modest decline in both stunting and wasting. Mizoram is the only state which shows a decline in all four indicators. Punjab (0.40) and Kerala (0.36) continue in the moderate category. Punjab is penalized on account of a dramatic rise in wasting, followed by overweight and a minimal reduction in anaemia. Whereas in case of Kerala, although there is a marginal decrease in stunting and anaemic children, with no reduction in wasting, however, there is a dramatic increase in the prevalence of overweight/obese children, and thus Kerala seems to have been penalized on this account. Andaman and Nicobar Island (0.42), Chandigarh (0.40), Lakshadweep (0.38) and Nagaland (0.37) were also found in the moderate category.
Manipur (0.33) jumps from moderate to low category and is the only state found in the low
category on the severity scale. It shows a significant reduction in stunting, wasting and
anaemia, although overweight children are found to increase in prevalence.

Except, Kerala, Jammu and Kashmir, Karnataka and Goa, all the states show a reduction in
MANUSH scores, between NFHS-3 and NFHS-4 (See Figure 2). Meghalaya shows maximum
improvement between the two rounds, followed by Tripura and Mizoram, accounting to 25%
or more reduction in MANUSH scores. Himachal Pradesh also shows about 23% reduction in
MANUSH scores. Madhya Pradesh and Bihar, the two states accounting to the maximum
burden of undernourished children, also show significant reduction of 17% -18% in MANUSH
scores, suggesting that these states are progressing in the right direction in terms of addressing
malnutrition, although steadily. Same is the case with Delhi, Assam, Manipur, Chhattisgarh,
Odisha, Andhra Pradesh, Uttar Pradesh and West Bengal that show 10%-15% reduction in
MANUSH scores. States like Jharkhand, Uttarakhand, Punjab, Arunanchal Pradesh, Haryana
and Tamil Nadu need to improve further as reduction between the two rounds is tardy, about
5-7%. Gujarat, Maharashtra, Rajasthan and Sikkim show the minimum decline (less than 5%),
suggesting extremely marginal improvement between the two rounds. States like Kerala,
Jammu and Kashmir and Karnataka, on the other hand, show a marginal increase (≤5%) in
MANUSH scores between two rounds, suggesting unbalanced development across the
dimensions. Goa shows about 11% increase in MANUSH scores and has been heavily
penalized on account of the unprecedented increase in wasting in children under the age of five.

Figure 2: Percent reduction in MANUSH scores across states in India between NFHS-3 and
NFHS-4 rounds of the survey

Recently released Comprehensive National Nutrition Survey (2016-18) conducted in 29 states
of India and Delhi (Union Territory), paints a better picture of nutrition status in children across
states in India, compared to previous two rounds of National Family Health Survey (See Figure 1c). None of the states is found in extremely alarming category (MANUSH score >0.65). Jharkhand continues to be an alarming category (0.56), although it shows a modest reduction in MANUSH scores between NFHS-4 and CNNS. Jharkhand shows a reduction in all parameters except wasting, which is found to be constant. Surprisingly, Nagaland (0.56) also joins the list of alarming category, showing the 2-scale downward shift from moderate category in NFHS-4. Nagaland is heavily penalized on account of a significant rise in overweight/obese children, followed by a marginal increase in wasting.

Madhya Pradesh (0.49), Gujarat (0.46) and Bihar (0.46) show an upward jump from severe to moderate category. While Madhya Pradesh and Bihar show a modest decline in all four dimensions, Gujarat, on the other hand, shows a significant decline in wasting and anaemia, although there is a marginal increment in stunting and no change is observed in overweight prevalence in children under the age of five. It is important to note that despite the decline in all parameters, Madhya Pradesh and Bihar have been penalized by MANUSH on account shortfall sensitivity since the reduction in the worse-off dimension (stunting) is not found to be proportionate to their best-off dimension (overweight). Assam (0.50) and Tripura (0.47) show a decline in performance and fall from moderate to severe category. Both Assam and Tripura have been penalized on account a significant increase in overweight/obese children. While wasting continue to increase in Assam, in Tripura, it is stunting, that is shown to increase between two surveys (NFHS-4 and CNNS). Maharashtra (0.47), Uttar Pradesh (0.47) and Meghalaya (0.46) continue to remain in a severe category despite a decrease in the MANUSH scores. While in Maharashtra, there has been a decrease in the prevalence of wasting and anaemia, no change is seen in the prevalence of stunting; moreover, overweight prevalence is on the rise. In Uttar Pradesh, the decline in stunting and anaemia is observed with increase in wasting and overweight in children at the same time. Meghalaya, on the other hand, shows a
decline in all four dimensions, and yet is penalized by MANUSH on account of shortfall 
sensitivity, i.e. the decline in its worse-off dimension, stunting, is not in proportion to decline 
in its best-off dimension, anaemia.

A large chunk of states is found in the moderate category in the Comprehensive National 
Nutrition Survey (2016-18). Sikkim (0.37) and Karnataka (0.42) show 2-scale improvement 
and move from alarming to moderate category. While Sikkim shows a significant decline in all 
four dimensions, Karnataka shows a major decline in anaemia, followed by stunting; however, 
overweight and wasting are seen to increase dramatically. Eight states, namely, Chhattisgarh 
(0.45), Jammu & Kashmir (0.42), West Bengal (0.42), Rajasthan (0.41), Haryana (0.40), Tamil 
Nadu (0.40), Arunanchal Pradesh (0.39) and Odisha (0.36) show an upward shift from severe 
to moderate category. Rajasthan and Odisha show decline in all parameters, yet they are 
penalized by MANUSH on account of shortfall sensitivity. In West Bengal and Tamil Nadu, 
all parameters show a decline in prevalence but wasting, which remains unchanged in case of 
West Bengal and is found to increase in Tamil Nadu. Similarly, Haryana also shows a decline 
in all dimensions, except stunting, which shows a slight increase. Chhattisgarh manages to 
reduce the prevalence of overweight significantly, followed by stunting and wasting, with no 
reduction in anaemia. In Jammu and Kashmir, there is a significant decline in both stunting and 
anemia, however wasting and overweight children tend to increase. On the contrary, 
Arunanchal Pradesh shows a significant decline in both wasting and anaemia, however stunting 
and overweight remain unaffected. Interestingly, Manipur (0.42), which ranked 1st in NFHS-4 
survey drops to 17th rank in CNNS, thus falling from low to moderate category, on account of 
the unprecedented rise in overweight/obese children, no change in prevalence of stunted and 
wasted children and slow decline in anaemic children. Andhra Pradesh (0.41), Telangana 
(0.40), Mizoram (0.39) and Delhi (0.39) continue in moderate category. While the prevalence 
of overweight in children seems to be a rise in both Telangana and Andhra Pradesh,
accompanied by a significant decline in anaemic children, a slight decrease in wasting in
observed in Telangana, which remains unaffected in Andhra Pradesh along with the prevalence
of stunting. On the other hand, Delhi which managed to reduce overweight significantly in
children between NFHS-3 and NFHS-4 is penalized in CNNS round on account of a high
prevalence of overweight children, while other indicators show a decline after NFHS-4.
Mizoram also shows a slight decrease in stunting and wasting, with a slight increase in anaemic
and overweight children. Uttarakhand (0.34) and Goa (0.34) move upwards from severe to low
category. Uttarakhand shows a decline in all dimensions with a significant reduction in wasting
and anaemia. Goa also shows a significant decline in wasting and anaemia, followed by
overweight. However, no change in the status of stunting is observed.

Himachal Pradesh (0.35), Punjab (0.34) and Kerala (0.28) move upwards from moderate to
low category. Both Himachal Pradesh and Punjab show a modest decline in wasting and
anaemia, with a slight increase in stunting. Prevalence of overweight seems to increase
significantly in Punjab between NHFS-4 and CNNS. Kerala, on the other hand, shows a rapid
decline in anaemia and overweight, followed by wasting, while stunting remains unaffected.

Comparison of three surveys – NFHS-3, NFHS-4 and CNNS reveal a paradigm shift in the
nutrition status of children under the age of five, across states in India as they are set in three
time periods. The study also reveals the usefulness of MANUSH method of aggregation in
bringing out inequalities within each dimension, making the comparison between two states or
within a state in two time periods more contextual.

b) Nutrition scenario across District Boundaries in India:

Next, we study the nutrition scenario across 640 districts of India, based on MANUSH score
and ranking. Since NFHS-4 is the only survey to provide district-level estimates for all districts
in India, we use data of this survey for our study. After calculating the MANUSH scores for
each district, they were grouped into low (<0.20), moderate (≥0.20 and <0.35), serious (≥0.35 and <0.50), alarming (≥0.50 and <0.65) and extremely alarming (≥0.65) category on a severity scale based on their respective MANUSH scores (See Figure 3).

Pockets of districts falling under extremely alarming, alarming, serious and moderate range emerge from the central and spread across the posterior end of the country in the said order. Two districts (Pashchimi Singhbhum of Jharkhand and The Dangs of Gujarat) fall in the extremely alarming range (score >0.65), followed by 145 districts in the alarming range, a large proportion belonging to Madhya Pradesh, Uttar Pradesh, Jharkhand, Bihar, Rajasthan and Gujarat. 352 districts fall in the serious range, 140 districts in the moderate range and only one district (Mokokchung district of Nagaland) in low range.

Of the districts falling in alarming and extremely alarming category (≥0.50 MANUSH score), i.e. a total of 147 districts, 40% of them have been penalized on account of high incidences of wasting, about 30% have been penalized due to high incidences of stunting and about 22% have higher prevalence of both stunting and wasting. Interestingly, Erode district in Tamil Nadu is severely penalized due to a very high incidence of overweight/obese children under the age of five. Few other districts like Chennai of Tamil Nadu, Ambala in Haryana, Banda of Uttar Pradesh, South District of Sikkim, and Ambala district of Haryana have been penalized on account of overweight/obese children in addition to undernourished children. All the districts in the bottom two category have medium to a high prevalence of anaemic children under the age of five.

The MANUSH score for estimating the triple burden of malnutrition also brings out the inequality that persists both at the inter-state and the intra-state level. Figure 4 below shows the
performance of each state along with the MANUSH scores obtained by the best and worst-performing districts in each state with respect to the state averages arranged in descending order. For some states, the spread is quite compact, e.g. in Andhra Pradesh and quite large for some, e.g. Odisha and, surprisingly, even Tamil Nadu.

Figure 4: States arranged on the basis of moving average of MANUSH scores of districts. Note: On the y-axis, the value in brackets indicates the number of districts in that particular state.

Interestingly, Odisha's best performing district (Cuttack) with undernutrition score of 0.21, ranks 4th in the country while its worst-performing district, Nabarangpur, with a score of 0.60, ranks 623rd is amongst the worst-performing districts in the country. Similarly, Kanyakumari of Tamil Nadu with a score of 0.22 ranks 7th in the country, while Chennai in Tamil Nadu ranks 611th and falls in the bottom list of worst-performing districts. Chennai shows higher prevalence in all the four indicators – overweight/obesity, stunting, wasting and anaemia in children under the age of five years. If one takes a closer look at the spread in the case of Odisha, the best and the worst-performing districts appear to form a cluster. A similar pattern is observed in West Bengal. In contrast to the case of Odisha and West Bengal, the states of Bihar and Madhya Pradesh each with 38 and 50 districts, have a low average MANSUH score for their state and a small deviation between the scores of their best performing and worst-performing districts, reflecting the uniformly poor performance across the state. Maharashtra, Karnataka and Rajasthan show a comparable spread. Such inequalities within and across states level reflect spatial heterogeneities that exist in India.

To study the spatial heterogeneity at the district level, we created Univariate LISA maps using MANUSH scores using GeoDa version 1.14.0. As shown in Figure 5a, we observe the formation of significant clusters (p<0.05) and the univariate Moran’s I value was found to be 0.619, depicting strong spatial autocorrelation. About 135 districts out of 640 districts, i.e. 20%
were surrounded by districts with high MANUSH scores, signifying clusters of high malnutrition, while 108 districts, i.e. around 17% districts were surrounded by districts with low MANUSH scores, signifying better nutrition scenario. The high-high clusters were mostly found in the central belt of India, in the states of Madhya Pradesh, Jharkhand, Maharashtra, Bihar, Rajasthan, Uttar Pradesh, Gujarat and some parts of Chhattisgarh, Odisha, West Bengal and Karnataka. While low-low clusters were found in the peripheral states of India – primarily in the north-eastern states like Nagaland, Manipur, Mizoram, some parts of Assam, Arunanchal Pradesh and Tripura, also in the northern states like Jammu & Kashmir, Himachal Pradesh and Punjab, in the southern coastal belt of Karnataka, Kerala and Tamil Nadu and in eastern coastal belt of Odisha and West Bengal. Interestingly, low-low clusters are also found in few districts of Telangana, bordering Andhra Pradesh. Spatial analysis also brought two groups of outliers, i.e. districts with low MANUSH scores (eight in count) surrounded by districts with high MANUSH scores, that can be grouped under 'positive outliers', and second, districts with high MANUSH score (seven in count) surrounded by districts with low MANUSH scores, that can be grouped under ‘negative outliers’.

Figure 5: Univariate LISA cluster maps of India showing the geographic clustering based on MANUSH scores across districts of India, a) with state boundaries, 2015-16. b) with state and NSS boundaries (as per 68th round of NSS), 2015-16.

Also, when we study the spatial clustering at the National Sample Survey (NSS) region level, the differences within a state become much more evident. NSS regions are the ones used for survey by National Sample Survey Organisation (NSSO) in conducting surveys across India on various socio-economic aspects since 1950. These regions are formed by contiguous grouping districts within a state, in relatively homogenous regions based on geographical features, rural population densities and crop-pattern [29]. As observed in Figure 5b, if one takes
a closer look at the spread in the case of Odisha, the best and the worst-performing districts appear to form significant clusters at coastal and southern NSS regions respectively. Similarly, in Karnataka and West Bengal, pockets of low performing and better performing districts appear at the anterior and posterior end, respectively, that are separated by NSS boundaries. Moreover, in states like Chhattisgarh and Bihar, significant clusters of poor-performing districts seem confined to a particular NSS region. A similar scenario is observed in Maharashtra, Gujarat and Rajasthan, where pockets of poor-performing districts seem to grouped together not only in a particular NSS region but also form clusters, across state boundaries, suggesting the spatial dependency of neighbours on malnutrition. Composite Indexing, thus, serves better in reflecting the burden and heterogeneities using spatial maps, which is difficult to estimate using single parameters.

3.3. Implications of MANUSH indexing on nutrition policy:

Scoring and ranking of states and district have become a common phenomenon in recent times, in India, for ease of comparison and prioritization of issues and for development of policies. However, there are two limitations that have been observed in this context. First, if scoring is based on a combination of indicators, linear averaging is the only method of aggregation used, whose limitations have already been discussed in the sections above. Second, if the scoring is done on single parameters, for example, only stunting or wasting or anaemia, and policy is developed based upon it, there is an increased risk of subduing effects of other indicators, not accounted.

To understand this, we compared a real scenario of a policy measure undertaken as part of recently launched National Nutrition Mission (NNM) in India whose objective is to reduce undernutrition in children, adolescent girls and women and achieve targets set for the year 2022 [8]. For accelerated intervention, districts were grouped into three phases, in the order of
priority. The priority was set solely based on the prevalence of stunting. The districts with the highest level of stunting were placed in the list of Phase I districts and so on. If the only objective were to reduce stunting, then this prioritization would have seemed rationale, but since objective is to reduce undernutrition holistically – stunting, wasting and anaemia, the three dimensions which are independent and not a substitute for other, hence, not considering other two dimensions, might have led to misallocation of priorities, funds and resources. To comprehend this better, we ranked the same 640 districts according to MANUSH scores and grouped into 3 priority regions – priority 1, 2 and 3. Districts with MANUSH score ≥0.48 were accorded 1st priority, districts with MANUSH score between 0.38 and 0.48 were placed in the 2nd priority list, and districts with MANUSH score less than 0.38 was put in 3rd priority list (see Additional File 1). It is to be noted that MANUSH index discussed in this article, also takes into account wasted and overweight children under the age of five, along with stunted and anaemic children. It needs to highlighted because targets set under the National Nutrition Mission, 2018 do not talk about the reduction in wasting and overweight/obese children, who are on the rise in India.

After grouping the districts into priority 1, 2 and 3 regions, we compared these districts with the priority districts under National Nutrition Mission (NNM), rolled out in three phases, as shown in Figure 6 below. About 8 districts (Dehradun, Ambala, Jamnagar, Chitradurga, Tiruvannamalai, Erode and Dharmapuri) which should have been part of phase 1 of NNM round as per MANUSH ranking, are listed in the 3rd phase of NNM. All the eight districts but Erode have been penalised on account of a high prevalence of wasting. Erode district of Tamil Nadu, on the other hand, is penalised on account of a high prevalence of overweight children, followed by stunted, wasted and anaemic children. If we focussed solely on indicators of undernutrition, then this district would have been neglected, but taking overweight as a measure
in MANUSH index, it pinpoints those districts as well who are becoming emerging capital of overnutrition, alongside undernutrition.

Similarly, 37 other districts, that should have been in phase 1 of NNM as per MANUSH ranking are part of the NNM 2nd phase. Majority of these districts too are penalised on the high prevalence of wasting, except South District of Sikkim and Mahe district of Pondicherry, who show a high prevalence of overweight/obese children under the age of five.

Moving further, 33 districts which should have been part of phase 2 of NNM as per MANUSH ranking are found in the list of districts under NNM 3rd phase. Three districts (Faridabad, Rewari and Kolkata) out of 33 mentioned have been penalised on account of the high prevalence of anaemia while two districts (Tawang of Arunanchal Pradesh and Namakkal of Tamil Nadu) have been penalised on account high incidence of overweight/obese children, while the rest of the districts exhibit high incidences of wasting. Interestingly, Mahamayanagar of Uttar Pradesh, one of the districts among the 33 mentioned above, exhibits a very high burden of stunting, and lower incidence of wasting, anaemia and overweight/obese. It has been penalised by MANUSH on account of unbalanced development across the dimension.

Figure 6: Map of India depicting phase allocation of districts as listed in a) National Nutrition Mission and b) as per MANUSH scores

Thus, MANUSH indexing becomes important on various fronts. First, it allows us to different aggregate dimensions together, taking care of the shortfall and hiatus across and within dimensions, thus prioritising steady improvement. Second, use of MANUSH scores, facilitates better understanding of not only the actual burden in the district and its status compared to other, in addition, it also points out which dimension needs further attention and to what extent the reduction is needed and thus can be helpful in prioritizing the intervention. This promotes decentralised and context-specific planning and programme implementation.
4. Conclusion

To summarise, in this paper, we first addressed the importance of choosing an appropriate method of aggregation in developing composite indices. We compared three methods of aggregation - linear, geometric and MANUSH. The new indexing method - MANUSH, was found to be more robust, as it fulfils six sets of conditions - Monotonicity, Anonymity, Normalisation and Uniformity, Shortfall Sensitivity and Hiatus Sensitivity to level. The first three are fulfilled by both linear aggregation method and the geometric mean method. Geometric Mean also fulfils an additional condition of Uniformity.

Second, we assessed the nutrition scenario at the state level using MANUSH scores over three different time periods, covered in three national surveys – NFHS-3 (2005-06), NFHS-4 (2015-16) and CNNS (2016-18). Though there is an overall progress in nutrition scenario from NFHS-3 to CNNS, we also find more significant inequalities in reduction across four dimensions. This was also indicated by the fact that in CNNS, most states were penalised by MANUSH, as opposed to the linear and geometric mean method.

Third, using MANUSH scores, we gauged at the nutrition scenario at the district level. Data from NFHS-4 was used in the study. Geographical heterogeneities were observed, and inequalities were reflected both within and across states. These variations in the geography were confirmed using spatial analysis. The spatial maps revealed the formation of significant clusters of high burden districts and low burden districts. These clusters were more prominent at NSS region within and across the state.

Finally, we studied the implication of ranking districts using MANUSH score for policy development using phasing of districts under the National Nutrition Mission as an example. We found that MANUSH indexing method is an appropriate tool for creating indices to estimate the burden of malnutrition at a different level of aggregation, taking different
dimensions into account, bringing out the inequalities and gaps and hence can serve a sound decision support system. This methodology can thus be applied to various contexts where the development is sought to be equitable and balanced.

This is the first-ever study to have estimated the triple burden of malnutrition in states and districts of India using a new compositing method – MANUSH. This is also among the fewer studies conducted to study the spatial heterogeneity existing within and across regions in India, using a composite score. One of the common complaints about the data on child nutritional levels has been its quality and frequency. With the availability of the NFHS-4 (2015-16) data right at the district level, we have a relatively up to date good quality baseline that could inform the National Nutrition Mission. CNNS (2016-18) followed it closely though it is available only at the state level. Fortunately, the NFHS – 5 survey is in progress, and the data is likely to be available in the near future, addressing the frequency issue. Use of MANUSH methodology for comparing the nutritional outcomes between NFHS-4 and NFHS-5 at the state and the district levels is likely to give valuable insights – we await this eagerly.

Abbreviations Used:

- MANUSH – Monotonicity Anonymity Normalisation Uniformity Shortfall Sensitivity
- Hiatus Sensitivity to level; SDGs – Sustainable Development Goals; NFHS – National Family Health Survey; CNNS – Comprehensive National Nutrition Survey; HDI – Human Development Index; UTs – Union Territories; WHO – World Health Organisation; LA – Linear Aggregation; GM – Geometric Mean
Declarations

Ethics approval and consent to participate:

This study compiled the data information from the state level fact sheets from National Family Health Survey, 2005–06, National Family Health Survey, 2015–16 and Comprehensive National Nutrition Survey, 2016–18 and district level fact sheets of National Family Health Survey, 2015–16 for India which is publicly available and with no access to personal identifiers.

Consent for publication:

Not applicable.

Availability of data and materials:

Data used in this study for analysis is publicly available and can be obtained from http://rchiips.org/NFHS/index.shtml and https://nhm.gov.in/index1.php?lang=1&level=2&sublinkid=1332&lid=713.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

AJ and SBA conceptualized and designed the study. AJ reviewed the literature for relevant data and documentation. AJ compiled the data, performed the analysis and prepared the primary draft of the manuscript. SBA edited and critically revised the manuscript. The manuscript is part of AJ's PhD work. Both authors read and approved the final manuscript.

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Additional Files:

File name: Additional File 1

File Format: Excel (.xls)

Additional File 1 consists of 9 worksheets.

Worksheet 1 Title: NFHS-3 scores & ranks (State)

Description: Calculation and Tabulation for computing Linear Aggregation (LA), Geometric Mean (GM) and MANUSH scores and Ranks using NFHS-3 data for States in India, 2005-06

Worksheet 2 Title: NFHS-4 scores & ranks (State)

Description: Calculation and Tabulation for computing Linear Aggregation (LA), Geometric Mean (GM) and MANUSH scores and Ranks using NFHS-4 data for States in India, 2015-16

Worksheet 3 Title: CNNS scores & ranks (State)

Description: Calculation and Tabulation for computing Linear Aggregation (LA), Geometric Mean (GM) and MANUSH scores and Ranks using CNNS data for States in India, 2016-18

Worksheet 4 Title: NFHS-4 scores & ranks (Districts)

Description: Calculation and Tabulation for computing Linear Aggregation (LA), Geometric Mean (GM) and MANUSH scores and Ranks using NFHS-4 data for Districts in India, 2016-18

Worksheet 5 Title: Monotonicity Cases

Description: Examples explaining Monotonicity axiom

Worksheet 6 Title: Uniformity Cases

Description: Examples explaining Uniformity axiom
Worksheet 7 Title: Shortfall Sensitivity Cases

Description: Examples explaining Shortfall Sensitivity axiom

Worksheet 8 Title: Hiatus Sensitivity Cases

Description: Examples explaining Hiatus Sensitivity to Level

Worksheet 9 Title: Districts under NNM and MANUSH

Description: List and ranking of districts phased under National Nutrition Mission (NNM) and its priority categorisation based on MANUSH scores