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Relationship among Anthropometric Indicators of Child Nutrition with Application to India

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Introduction

Height-for-age, weight-for-height and weight-for-age are the three most commonly used anthropometric measures to assess the nutritional status of children. Height-for-age and weight-for-height reflect distinct biological process [1]. Height-for-age reflects the linear growth while weight-for-height reflects the ponderal growth. A child is classified as stunted if its height is less than the reference or the standard height corresponding to the age of the child. Similarly, a child is classified as wasted if its weight-for-height is less than the reference or the standard weight-for-height. Finally, a child is classified as under-weight if its weight is less than the reference or the standard weight for the age of the child. Weight reflects the body mass and depends on both linear and ponderal growth but fails to distinguish between the two. The proportion of children stunted, the proportion of children wasted and the proportion of children under-weight reflect the prevalence of under-nutrition in children in their own context. The three proportions are not the same and none of the three reflects the multidimensional nature of child under-nutrition[2].

Although, assessment of the nutritional status of a child on the basis of its weight is complex because of its composite nature, yet weight has traditionally been used to estimate the prevalence of under-nutrition in children. Gomez et al[3] proposed a classification based on deficit in weight for age which was later modified by Jelliffe[4]. An Expert Committee constituted jointly by the FAO, and the WHO emphasised in 1971 the need of distinguishing between acute and chronic under-nutrition[5] following which Waterlow and Rutishauser[6] proposed the stunting-wasting classification to assess child under-nutrition. Subsequently an FAO/UNICEF/WHO Expert Committee also recommended the use of height-for-age and weight-for-height as primary indicators of the nutritional status of the child[7].

In India, however, assessment of child under-nutrition continues to be based on weight-for-age. India's official Integrated Child Development Scheme[8], the main plank to address the challenge of child under-nutrition in the country, continues to classify a child as under-nourished if the weight of the child is lower than the reference or the standard weight for the age of the child[9]. Although, estimates of the prevalence of under-weight, stunting and wasting in children are also available through the nationally representative household survey such as the National Family Health Survey and the recent Rapid Survey of Children, yet, there is no system under the Integrated Child Development Scheme to identify whether a child is stunted (low height-for-age) or wasted (low weight-for-height). The scheme continues to rely upon the weight-for-age classification to assess the nutritional status of the child.

Recently, the rationale of using weight-for-age to measure child under-nutrition has been questioned[10]. It is argued that prevalence of under-weight substantially under estimates the true prevalence of child under-nutrition[2][11]. Svedberg has argued that weight-for-age is the product of height-for-age and weight-for-height and therefore assessment of child under-nutrition on the basis of child weight misses some children who are either stunted or wasted. He has therefore proposed a composite index of anthropometric failure (CIAF) to measure the true prevalence of child under-nutrition. CIAF counts all children who are either under-weight or stunted or wasted. CIAF proposed by Svedberg is based on the classification of children into six groups - five groups comprising of children with at least one anthropometric failure and the sixth group comprising of children with no anthropometric failure. Nandy et al[12] and Gaiha, Jha and Kulkarni[13] however identified one more group of children who are neither stunted nor wasted but under-weight. A number of studies have however highlighted limitations of CIAF[14][15] and new indexes to overcome these drawbacks have been suggested[16].

A concern with all anthropometric indices used to assess nutritional status of children including CIAF is that they are head count ratios. They do not reflect the nutrition gap - the difference between the anthropometric measurements of a child from the respective reference or standard - and hence tell little about the depth and the severity of under-nutrition[17]. As such, different anthropometric indicators used to measure the nutritional status of children are of little help in analysing the nutritional inequality which is important from the view point of improving the nutritional status of children. There may well be a situation that nutritional inequality increases despite a decrease in the prevalence of under-nutrition or vice versa. Recently, Mukhopadhyay[18] has used the mean of the squared deviation to measure the level, depth and severity of under-nutrition in India.

This paper has two objectives. The first objective is to decompose the nutrition gap in terms of child weight into nutrition gap in terms of child height and nutrition gap in terms of weight per unit height of the child. This decomposition allows to estimate how much of the deficit in child weight is accounted by the deficit in child height and by the deficit in weight per unit height of the child. Deficit in child weight reflects faltering in the growth of body mass while deficit in height reflects faltering in linear growth and deficit in weight per unit height reflects faltering in ponderal growth. The second objective of the paper is to apply the decomposition framework developed in this paper to revisit the situation of child under-nutrition in India to explore the relative contribution of linear growth faltering and ponderal growth faltering to faltering of body mass growth in Indian children.

The paper is organised as follows. The next section of the paper develops the decomposition framework that links the child weight with child height and weight per unit height of the child. The third section applies the decomposition framework to the Indian data available from the three rounds of the National Family Health Survey carried out in 1992-93; 1998-99 and 2005-06. The findings of the decomposition analysis are discussed in the last section of the paper which also highlights programmatic implications of the findings of the analysis in the context of reducing and ultimately eliminating the scourge of child under nutrition in India.

Decomposition of the Child Weight

We start with the arguments put forward by Svedberg[(2)] that neither weight-for-age, nor height-for-age not weight-for-height reflect the true prevalence of under-nutrition. His arguments are based on the identity

$$W/A = H/A * W/H$$

where W is the weight, H is the height and A is the age. It may be noticed that the identity mentioned by Svedberg is essentially a notional identity and not a mathematical identity. The weight and height are variables whereas age is essentially a reference point so that weight-per-unit age and height-per-unit-age carries little analytical meaning but only a notional representation. It cannot be used for any analytical purpose.

From the analytical perspective, the weight of a child of any age can be expressed as the product of its height and weight per unit height. In other words

$$W = H*(W/H) = H*U$$

where $U=W/H$ is the weight per unit height of the child. The standard approach to measure the nutritional status of the child is to compare the weight and height of the child with the weight and height of the reference child. If W_r is the weight and H_r is the height for the reference child, then

$$W_r = H_r*(W_r/H_r) = H_r*U_r$$

Now

$$W/W_r = (H/H_r)*(U/U_r) \qquad (1)$$

or

$$\text{Log}(W/W_r) = \text{Log}(H/H_r)+\text{Log}(U/U_r)$$

Where Log is the logarithm to the base 10. In other words,

$$\nabla W = \nabla H+\nabla U \qquad (2)$$

where

$$\nabla W = \text{Log}(W/W_r), \text{ etc.}$$

∇W reflects the difference between the weight of the child and the weight of the reference child. Similarly, ∇H reflects the difference between the height of the child and height of the reference child while ∇U reflects the difference between the weight per unit height of the child and the weight per unit height of the reference child. Equation (2) thus shows that the difference between the weight of the child and the weight of the reference can be decomposed into two parts, one attributed to the difference between the height of the child and the height of the reference child and the other attributed to the difference between the weight per unit height of the child and weight per unit height of the reference child. Equation (2) thus tells how much of the difference in the growth of body mass is due to the difference in linear growth and how much of the difference is due to ponderal growth.

The difference ∇U may be further decomposed into two components. If W_h denotes the reference or expected weight of the child corresponding to its actual height and $U_h=W_h/H$, then

$$\nabla U = \text{Log}(U/U_r) = \text{Log}((U/U_h)*(U_h/U_r)) = \text{Log}(U/U_h)+\text{Log}(U_h/U_r)$$

$$\nabla U = \nabla U_h+\nabla U_r$$

where

$$\nabla U_h = \text{Log}(U/U_h), \text{ and } \nabla U_r = \text{Log}(U_h/U_r)$$

Equation (2) can now be written as

$$\nabla W = \nabla H+\nabla U_h+\nabla U_r \qquad (3)$$

Equation (3) decomposes the difference in weight into three components: 1) difference in the height of the child from the height of the reference child; 2) difference in child weight and reference or expected weight corresponding to the child height; and 3) difference between expected or reference weight corresponding to the child height and weight corresponding to the height of the reference child. By definition, ∇U_h is a measure of wasting. ∇U_r, on the other hand, is the difference between the ratio of the reference weight of the child to the weight of the reference child and the height of the child to the height of the reference child. It reflects the thinness which is a marker of poor nutritional status, although thin children may not necessarily be under-nourished.

It is obvious that ∇W, as well as ∇H, ∇U, ∇U_h and ∇U_r can be both positive and negative. When $\nabla W<0$, the child is classified as under-weight (W); when $\nabla H<0$, the child is classified as stunted (S), and when $\nabla U<0$, the child is classified as low weight per unit height (U). Similarly, when $\nabla U_h <0$, the child is classified as wasted (U1). Finally, $\nabla U_r<0$ implies that the ratio of the reference weight with respect to child height is less than the ratio of the weight to height of the reference child (U2). Equation (2) suggests that when $\nabla H<0$ and $\nabla U<0$, ∇W is always negative or the child is always under-weight. Similarly, when $\nabla H\geq 0$ and $\nabla U\geq 0$, ∇W is always positive. However, when the sign of ∇H and ∇U is different, the sign of ∇W depends on the sign and magnitude of ∇H and ∇U as shown in table 1. The classification given in table 1 is the same as proposed by Svedberg (2000).

Arguing in the same manner, equation (3) which is an extension of equation (2) suggests that the sign of the difference ∇W depends upon the sign and the magnitude of the difference ∇H, ∇U_h and ∇U_r. When the decomposition described in equation (3) is used, a child can be classified into one of the possible 14 categories as shown in table 2. It may be seen from the table that a child can be under-weight (low weight-for-age) even if it is neither stunted nor wasted as observed by Nandy et al[12] and Gaiha, Jha and Kulkarni[13]. This is the case when $\nabla H\geq 0$, $\nabla U_h\geq 0$ and $\nabla U_r<0$ but $|\nabla U_r|\leq|\nabla H+\nabla U_h|$. It is also obvious that when $\nabla U_r=0$ and $\nabla U=\nabla U_h$ and equation (3) reduces to equation (2). In other words, ∇U_r reflects the stunting effect on wasting and shows that the larger is the difference between H and H_r, the larger is the difference ∇U_r. Finally, if we ignore ∇U_r then the classification presented in table 2 reduces to classification presented in table 3 which is the same as proposed by Nandy[12] and observed by Gaiha, Jha and Kulkarni[13].

Equations (2) and (3) provide the theoretical basis in support of the classification proposed by Svedberg[2] and Nandy et al[12]. At the same time, equation (2) and (3) also suggest that the classification proposed by Svedberg is essentially different from the classification proposed by Nandy et al[12] in the context of measuring the ponderal growth faltering. It is therefore obvious that the composite index of anthropometric failure derived on the basis of the classification proposed by Svedgerg (Table 1) is essentially different from the composite index of anthropometric failure derived from the classification proposed by Nandy et al (Table 3).

The foregoing discussions suggest that a key consideration in assessing the nutritional status of children is related to the reference for measuring ponderal growth faltering. McLaren and Read (1972; 1975) have recommended use of the weight per unit height of the reference child (∇U) whereas Waterlow and Rutishauser (1974) have suggested use of the reference weight per unit height of the child (∇U_h). When ∇U is used for the purpose of classification, there is no child who is neither stunted nor low weight per unit height but under-weight. However, when ∇U_h is used for the purpose of classification, then there is a proportion of children who are under-weight despite the fact that these children are neither stunted nor wasted. Since, $\nabla U=\nabla U_h+\nabla U_r$, it is obvious that proportion of children with $\nabla U<0$ is always greater than or equal to the proportion of children with $\nabla U_h<0$.

Equations (2) and (3) hold for every child. Averaging ∇W, ∇H and ∇U over all under-weight $\nabla W<0$ children, the average deficit in weight $Avg(\nabla W)$ can be decomposed into average deficit in height $Avg(\nabla H)$ and average deficit in weight per unit height $Avg(\nabla U)$

$$Avg(\nabla W) = Avg(\nabla H)+Avg(\nabla U) \quad (4)$$

or

$$Avg(\nabla W) = Avg(\nabla H)+Avg(\nabla U_h)+Avg(\nabla U_r) \quad (5)$$

Similarly, average of the squared deficit in weight or the variance of the deficit in weight $Var(\nabla W)$ can be decomposed as

$$Var(\nabla W) = Var(\nabla H)+Var(\nabla U)+2Cov(\nabla H,\nabla U) \quad (6)$$

or

$$Var(\nabla W) = Var(\nabla H)+Var(\nabla U_h)+Var(\nabla U_r)+ 2Cov(\nabla H,\nabla U_h)+2Cov(\nabla H,\nabla U_r)+2Cov(\nabla U_h,\nabla U_r) \quad (7)$$

Here *Cov* stands for covariance. Assuming that covariance between two variables is distributed equally, between variables, we get

$$Var(\nabla W) = [Var(\nabla H)+Cov(\nabla H,\nabla U)]+[Var(\nabla U)+Cov(\nabla H,\nabla U)] = A+B \quad (8)$$

Similarly,

$$
\begin{aligned}
Var(\nabla W) &= [Var(\nabla H)+Cov(\nabla H,\nabla U_h)+Cov(\nabla H,\nabla U_r)]+ \\
&\quad [Var(\nabla U_h)+Cov(\nabla H,\nabla U_h)+Cov(\nabla U_h,\nabla U_r)]+ \\
&\quad [Var(\nabla U_r)+Cov(\nabla H,\nabla U_r)+Cov(\nabla U_h,\nabla U_r)] \\
&= A+C+D \qquad (9)
\end{aligned}
$$

Equations (4) shows that the average deficit in W can be decomposed into average deficit in H and average deficit in U or equivalently average deficit in U_h, and average deficit in U_r (Equation 5). Similarly, equation (8) shows that the average squared deficit in W can be decomposed into the average squared deficit in H and average squared deficit in U whereas equation (9) shows that the average squared deficit in W can be decomposed into average squared deficit in H, average squared deficit in U_h and average squared deficit in U_r. In other words, equations (4) and (5) analyse how linear growth faltering and ponderal growth faltering contributes to the faltering in the growth of body mass of the child. Similarly, equations (8) and (9) analyse how the severity of faltering in linear growth and severity of faltering of ponderal growth contribute to the severity of faltering in the growth of the body mass in child.

Evidence from India

We apply the analytical framework developed above to revisit the nutritional status of children below three years of age in India. The analysis is based on the data available through the three rounds of nationally representative National Family Health Survey - 1992-93; 1998-99; and 2005-06. Details about the methodology and coverage of these surveys are given elsewhere[19][20][21]. During these surveys, weight and height of all children below 3 years of age in the households selected for the survey were measured following the standard anthropometric measurement methods. Based on the values of height and weight of children collected during the survey, z-score was calculated using the WHO Standards for height-for-age and weight-for-age and weight-for-height of children as standard and weight-for-age, height-for-age and weight-for-height corresponding to the z-score of -2 were taken as the reference[22]. At the first step of the analysis, outliers in the data sets used in the analysis were detected on the basis of z-scores for weight-for-age, height-for-age and weight-for-height and children having either extremely low (z<-6) or extremely high (z>6) z-scores in terms of either in weight-for-age or in height-for-age or in weight-for-height were excluded so that the analysis is limited to 20831 children below three years of age surveyed during 1992-93; 25490 children surveyed during 1998-99 and 24904 children surveyed during 2005-06.

a. Prevalence of Under-nutrition. Estimates of the prevalence of under-nutrition in India are presented in tables 4 through 6 on the basis of the classifications described in tables 1 to 3. The prevalence of under-weight and the prevalence of stunting are the same in the three classifications but the prevalence of weight per unit height as obtained in classification I is different from the prevalence of wasting in classification III because weight per unit height is measured relative to the weight per unit height of the reference child whereas wasting is measured relative to the reference weight per unit height of the child. As a result, the proportion of children who are under-weight as well as stunted and low weight for height is substantially higher in classification I than in classification III. Similarly, the CIAF and the proportion of children low weight for height in classification I is substantially higher than the prevalence of wasting in classification III.

The classification II brings in the element of thinness in the assessment of the nutritional status of children (Table 5). Quite interestingly, more than 80 per cent children in the country are thin in the sense that the ratio of the expected or reference weight to the height of these children is less than the ratio of weight to height of the respective reference children. Table 4 also indicates that almost 40 per cent of these children are neither stunted, not wasted nor under-weight or their nutritional status is normal. Although, there is no faltering of the growth of the body mass of these children or the faltering of their linear growth or faltering of their ponderal growth, yet the expected growth of the body mass of these children relative to their height is less than the weight of the reference child relative to its height. Incidentally, the proportion of children who are thin but not under-nourished as they are neither stunted nor wasted nor under-weight is substantially higher than the proportion of children who are wasted or low weight for the height of the child. This indicates that there exists substantial nutritional deficiency even in those children who are otherwise classified as not stunted, not wasted and not under-weight. This nutritional deficiency among the 'normal' is not reflected either in classification I and or in classification III but has implications for child growth and development.

Finally, it may be noticed from table 5 that if thinness is not taken into consideration then the Composite Index of Anthropometric Failure obtained from table 5 is the same as the Composite Index of Anthropometric Failure obtained from table 6. However, if thinness of children is also considered as a sign of nutritional deficiency then it is obvious from table 5 that almost 90 per cent children in India suffer from some type of nutritional deficiency. Moreover, there appears little change in this proportion during the 15 years under reference. At the same time, the proportion of children who are thin but not under-nourished has increased substantially over time.

The difference in the nutritional status of children based on of classification I and based on classification III becomes more sharp when stunting and wasting are considered simultaneously. When the assessment is based on classification I, almost one fifth of the children in 2005-06 were stunted as well as low weight for height (SU) whereas another one fifth were stunted but not low weight for height (S). On the other hand, around 17 per cent children were low weight for height but not stunted (U) so that around 43 per cent children in India were neither stunted not low weight for height (N) in 2005-06. However, when assessment is based on classification III, less than 8 per cent children were either stunted or wasted or both (SU1), about one third were stunted but not wasted (S), around 14 per cent were wasted but not stunted (W) so that around 46 per cent children were neither stunted nor wasted (N). Use of classification III, thus, lowers the proportion of children who falter in both linear and ponderal growth the proportion of children who falter in linear growth. Table 4 also shows that there is no child according to classification I who is neither stunted nor low weight for height but under-weight whereas there are more than 4 per cent such children in 2005-06 according to classification III who are under-weight despite the fact that they are neither stunted nor low weight for height. It is also clear that the two classifications will give the same assessment only when ∇U_r=0 which means that a child taller than the reference child must also be heavier than the reference child and a child shorter than the reference child must also be lighter than the reference child [23][24].

b. Depth of Under-nutrition. Table 7 presents average values of ∇W, ∇H, ∇U, ∇U_h and ∇U_r for under-weight (∇W<0) children or for children in which the growth of the body mass has faltered. It may be seen from the table that faltering in the growth of the body mass, on average, is primarily due to the faltering of the ponderal growth and the contribution of the faltering of the linear growth is on average secondary. On the other hand, when ∇U is decomposed into ∇U_h and ∇U_r, then only about 5 per cent of $Avg(\nabla W)$ is accounted by $Avg(\nabla U_h)$ but more than 72 per cent of the $Avg(\nabla W)$ is accounted by $Avg(\nabla U_r)$. It is also evident from the table that the role of the faltering in the linear growth in deciding faltering in the growth of the body mass has decreased over time but that of the linear growth has increased. This means that faltering in the ponderal growth is getting more and more dominant in deciding the faltering in the growth of the body mass of Indian children while that of linear growth is getting less and less relevant. When the faltering in the ponderal growth is decomposed further, the dominance of the weight component of faltering in the ponderal growth may be seen getting more dominant compared to the height component of faltering in the ponderal growth. This observation again confirms that faltering in the growth of the body mass of Indian children is primarily due to faltering of the ponderal growth. The effect of the faltering of the linear growth on faltering in the growth of the body mass is not so dominant.

Table 7 also tells that the average weight of under-nourished children in India was around 89.3 per cent of the weight of the reference child in 2005-06 and this proportion has increased over time showing the weight deficit of India children has decreased, on average, albeit slowly. Similarly, the average height of the under-nourished children was around 97.5 per cent of the height of the reference child while the average weight per unit height of the under-nourished children was 91.6 per cent of weight per unit height of the reference child in 2005-06. However, the average deficit in height remains unchanged between 1992-93 and 1998-99 but decreased sharply between 1998-99 and 2005-06 whereas the average deficit in weight per unit height decreased between 1992-93 and1998-99 but increased during between 1998-99 and2005-06. On the other hand, the ratio (U/U_h) was more than 1 in 1992-93 and 1998-99 but decrease in 2005-06 but the ratio (U_h/U_r) increased throughout the period under reference. If there had been no decrease in the ratio (U/U_h), then the narrowing down of the weight deficit would have been even faster between 1998-99 and 2005-06.

c. Severity of Under-nutrition. The variation in weight gap (∇W) in children with $\nabla W<0$ reflects the severity in under-nutrition in terms of weight or severity of the faltering of the growth of the body mass which may be decomposed into the severity of linear growth faltering and severity of ponderal growth faltering or both according to equations (8) and (9). Results of the decomposition of the severity of faltering in the growth of the body mass are presented in table 8. The primary contributor to the severity of the faltering of the growth of body mass has been the severity in faltering of the ponderal growth and this contribution appears to have increased over time. By comparison, the contribution of the severity in the linear growth faltering to the severity in the faltering of the growth of the body mass has comparatively been found to be small and this contribution appears to have decreased over time.

It may also been seen from the table 8 that the contribution of the severity of the faltering of ponderal growth to the severity of the faltering of the growth of the body moss has increased over time. When the ponderal growth faltering is measured in terms of ∇U, more than 80 per cent of the severity of growth faltering in body mass in 2005-06 is accounted by the severity of ponderal growth faltering and this proportion has increased over time. On the other hand, when the ponderal growth faltering is measured in terms of ∇U_h, almost two-third of the severity of growth faltering in body mass is accounted by the severity in ponderal growth faltering and this proportion has also increased over time. This means that reduction in the severity of ponderal growth faltering is critical to reducing the severity of growth faltering in the body mass of Indian children. By comparison, the severity of linear growth faltering is not so important in deciding as well as reducing the severity of the faltering in the growth of the body mass.

Discussions and Conclusions

We have shown in this paper that the level, depth and severity of growth faltering in body mass, measured in terms of weight-for-age, can be decomposed into level, depth and severity of linear growth faltering and level, depth and severity of ponderal growth faltering. On the basis of this decomposition, we have also provided theoretical justification of classification of the nutritional status of children proposed by Svedberg[(2)] and modified by Nandy, et al[(12)]. The decomposition analysis also suggests that essential difference between Svedberg classification and the modified classification proposed by Nandy et al is the way ponderal growth faltering is measured. When the ponderal growth faltering is measured relative to the weight and height of the reference child, the decomposition analysis presented here leads to the classification proposed by Svedberg. However, when ponderal growth faltering is measured relative to the reference weight for the height of the child, the decomposition analysis leads to the classification suggested by Nandy et al. Measuring the ponderal growth faltering relative to the reference weight for the height of the child, however, leads to an under-estimation of the prevalence of under-nutrition as measured in terms of CIAF - the proportion of children with at least one anthropometric failure. Moreover, it also leads to substantially low prevalence of ponderal growth faltering. Another anomaly associated with the use of the reference weight for the height of the child to measuring ponderal growth faltering is that some children are classified as under-weight (low weight-for-age) despite the fact that they are neither low height-for-age (stunted) nor low weight-for-height (wasted). These measurement problems can be effectively addressed when the ponderal growth faltering is measured relative to the weight and weight of the reference child and not in relative to the reference weight for the height of the child. The decomposition framework also suggests that when ponderal growth faltering is measured relative to the weight and height of the reference child, faltering in the growth of body mass is fully explained by faltering in ponderal growth and faltering in linear growth. This is however not the case when ponderal growth faltering is measured relative to the reference weight for child height.

The application of the decomposition framework to the Indian data indicates different classifications depict different situation of child under-nutrition in the country, especially in the context of faltering in the ponderal growth. When the ponderal growth is measured relative to the weight and height of the reference child, then the primary determinant of the level, depth and severity of faltering in the growth of body mass in the Indian children is the faltering in the ponderal growth and not the faltering in the linear growth. Moreover, a substantial proportion of children in the country are thin in the sense that their weight per unit height is less than the weight per unit height of the reference child, although, they are not under-nourished in the sense that these children are neither under-weight, nor stunted, not wasted. In these children, the ratio of the child weight to the reference weight for the child height is less than the weight per unit height of the reference child. These children remain out of the gambit of the efforts directed towards tackling the problem of under-nutrition in children such as the Integrated Child Development Scheme of India because they are classified as normal children. Addressing nutritional deficiencies of these 'normal' children is one of those dimensions of under-nutrition which has not been covered under the existing efforts directed towards addressing the challenge of under-nutrition.

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Table 1

Classification of nutritional status on the basis of equation (2)

	Combination	Direction of ∇W_a	Classification
1.1	∇H<0, ∇U<0	∇W <0	S,U,W
1.2	∇H<0, $\nabla U \geq 0$	If $\lvert \nabla H \rvert > \lvert \nabla U \rvert$, ∇W<0	S,W
1.3	∇H<0, $\nabla U \geq 0$	If $\lvert \nabla H \rvert \leq \lvert \nabla U \rvert$, $\nabla W \geq 0$	S
1.4	$\nabla H \geq 0$, ∇U<0	If $\lvert \nabla U \rvert > \lvert \nabla H \rvert$, ∇W<0	U,W
1.5	$\nabla H \geq 0$, ∇U<0	If $\lvert \nabla U \rvert \leq \lvert \nabla H \rvert$, $\nabla W \geq 0$	U
1.6	$\nabla H \geq 0$, $\nabla U \geq 0$	$\nabla W \geq 0$	N

Table 2

Classification of nutritional status on the basis of equation (3)

	Combination	Direction of ∇W_a	Classification
2.1	$\nabla H<0$, $\nabla U_h<0$, $\nabla U_r<0$	$\nabla W<0$	S,U1,U2,W
2.2	$\nabla H<0$, $\nabla U_h<0$, $\nabla U_r\geq 0$	If $\|\nabla H+\nabla U_h\|>\|\nabla U_r\|$, $\nabla W<0$	S,U1,W
2.3	$\nabla H<0$, $\nabla U_h<0$, $\nabla U_r\geq 0$	If $\|\nabla H+\nabla U_h\|\leq\|\nabla U_r\|$, $\nabla W\geq 0$	S,U1
2.4	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla U_r<0$	If $\|\nabla H+\nabla U_r\|>\|\nabla U_h\|$, $\nabla W<0$	S,U2,W
2.5	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla U_r<0$	If $\|\nabla H+\nabla U_r\|\leq\|\nabla U_h\|$, $\nabla W\geq 0$	S,U2
2.6	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla U_r\geq 0$	If $\|\nabla H\|>\|\nabla U_h+\nabla U_r\|$, $\nabla W<0$	S,W
2.7	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla U_r\geq 0$	If $\|\nabla H\|\leq\|\nabla U_h+\nabla U_r\|$, $\nabla W\geq 0$	S
2.8	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla U_r<0$	If $\|\nabla U_h+\nabla U_r\|>\|\nabla H\|$, $\nabla W<0$	U1,U2,W
2.9	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla U_r<0$	If $\|\nabla U_h+\nabla U_r\|\leq\|\nabla H\|$, $\nabla W\geq 0$	U1,U2
2.10	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla U_r\geq 0$	If $\|\nabla U_h\|>\|\nabla H+\nabla U_r\|$, $\nabla W<0$	U1,W
2.11	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla U_r\geq 0$	If $\|\nabla U_h\|\leq\|\nabla H+\nabla U_r\|$, $\nabla W\geq 0$	U1
2.12	$\nabla H\geq 0$, $\nabla U_h\geq 0$, $\nabla U_r<0$	If $\|\nabla U_r\|>\|\nabla H+\nabla U_h\|$, $\nabla W<0$	U2,W
2.13	$\nabla H\geq 0$, $\nabla U_h\geq 0$, $\nabla U_r<0$	If $\|\nabla U_r\|\leq\|\nabla H+\nabla U_h\|$, $\nabla W\geq 0$	U2
2.14	$\nabla H\geq 0$, $\nabla U_h\geq 0$, $\nabla U_r\geq 0$	$\nabla W\geq 0$	N

Table 3

Classification of nutritional status derived from table 2 after ignoring ∇U_r

	Combination	Table 2 categories	Classification
3.1	$\nabla H<0$, $\nabla U_h<0$, $\nabla W<0$	2.1 and 2.2	S,U1,W
3.2	$\nabla H<0$, $\nabla U_h<0$, $\nabla W\geq 0$	2.3	S,U1
3.3	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla W<0$	2.4 and 2.6	S,W
3.4	$\nabla H<0$, $\nabla U_h\geq 0$, $\nabla W\geq 0$	2.5 and 2.7	S
3.5	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla W<0$	2.8 and 2.10	U1,W
3.6	$\nabla H\geq 0$, $\nabla U_h<0$, $\nabla W\geq 0$	2.9 and 2.11	U1
3.7	$\nabla H\geq 0$, $\nabla U_h\geq 0$, $\nabla W<0$	2.12	W
3.8	$\nabla H\geq 0$, $\nabla U_h\geq 0$, $\nabla W\geq 0$	2.13 and 2.14	N

Remarks: Nandy et al[12] has also mentioned that 3.3 is not possible.

Table 4

Prevalence of under-nutrition in India, 1992-2006

Classification I			1992-93	1998-99	2005-06
1.1	S,U,W	Stunted, Low weight for height, Under-weight	25.5	23.0	19.6
1.2	S,W	Stunted, Under-weight	7.2	7.1	5.4
1.3	S	Stunted	16.6	18.0	15.0
1.4	U,W	Low weight for height, Under-weight	10.0	9.0	10.3
1.5	U	Low weight for height	4.9	4.8	6.5
1.6	N	Normal	35.7	38.1	43.1
Prevalence of under-weight			42.7	39.0	35.4
Prevalence of stunting			49.4	48.1	40.1
Prevalence of low weight for height			40.4	36.8	36.4
Comprehensive Index of Anthropometric Failure			64.3	61.9	56.9

Source: Author's calculations

Table 5

Prevalence of under-nutrition in India, 1992-2006

Classification II			1992-93	1998-99	2005-06
2.1	S,U1,U2,W	Stunted, Wasted, Thin, Under-weight	9.9	8.1	7.8
2.2	S,U1,W	Stunted, Wasted, Under-weight	0.0	0.0	0.0
2.3	S,U1	Stunted, Wasted	0.0	0.0	0.0
2.4	S,U2,W	Stunted, Thin, Under-weight	22.8	21.9	17.3
2.5	S,U2	Stunted, Thin	16.6	18.0	15.0
2.6	S,W	Stunted, Under-weight	0.0	0.0	0.0
2.7	S	Stunted	0.0	0.0	0.0
2.8	U1,U2,W	Wasted, Thin, Under-weight	6.4	5.6	6.6
2.9	U1,U2	Wasted, Thin	1.1	0.9	1.4
2.10	U1,W	Wasted, Under-weight	1.3	1.4	1.7
2.11	U1	Wasted	3.2	3.4	4.5
2.12	U2,W	Thin, Under-weight	2.3	1.9	2.0
2.13	U2	Thin	28.0	30.1	33.4
2.14	N	Normal	8.4	8.6	10.3
Prevalence of under-weight			42.7	39.0	35.4
Prevalence of stunting			49.4	48.1	40.1
Prevalence of wasting			21.9	19.4	22.0
Prevalence of thinness			87.2	86.7	83.5
Composite Index of Anthropometric Failure (Without thinness)			63.7	61.4	56.3
Composite Index of Anthropometric Failure (With thinness)			91.6	91.4	89.7

Source: Author's calculations

Table 6

Prevalence of under-nutrition in India, 1992-2006

Classification III			1992-93	1998-99	2005-06
3.1	S,U1,W	Stunted, Wasted, Under-weight	9.9	8.1	7.8
3.2	S,U1	Stunted, Wasted	0.0	0.0	0.0
3.3	S,W	Stunted, Under-weight	22.8	21.9	17.3
3.4	S	Stunted	16.6	18.0	15.0
3.5	U1,W	Wasted, Under-weight	7.7	7.0	8.3
3.6	U1	Wasted	4.3	4.3	5.9
3.7	W	Under-weight	2.3	1.9	2.0
3.8	N	Normal	36.3	38.6	43.7
Prevalence of under-weight			42.7	39.0	35.4
Prevalence of stunting			49.4	48.1	40.1
Prevalence of wasting			21.9	19.4	22.0
Composite Index of Anthropometric Failure			63.7	61.4	56.3

Source: Author's calculations

Table 7

Average difference in terms of different anthropometric indices

Year	*Avg*(∇W)	*Avg*(∇H)	*Avg*(∇U)	*Avg*(∇U_h)	*Avg*(∇U_r)
1992-93	-0.0538	-0.0170	-0.0367	0.0047	-0.0414
	100.0	31.7	68.3	-8.8	77.0
1998-99	-0.0514	-0.0169	-0.0345	0.0065	-0.0410
	100.0	32.9	67.1	-12.7	79.8
2005-06	-0.0492	-0.0112	-0.0380	-0.0024	-0.0355
	100.0	22.8	77.2	4.9	72.3
	W/W_r	H/H_r	U/U_r	U/U_h	U_h/U_r
1992-93	0.884	0.962	0.919	1.011	0.909
1998-99	0.888	0.962	0.924	1.015	0.910
2005-06	0.893	0.975	0.916	0.994	0.921

Source: Author's calculations

Table 8
Inequality in under-nutrition

Year	$Var(\nabla W)$	$Var(\nabla W)$ accounted by variation in			
		∇H	∇U	∇U_h	∇U_r
		A	*B*	*C*	*D*
1992-93	0.0019	0.0004	0.0015	0.0011	0.0004
	100.0	20.2	79.8	57.5	22.3
1998-99	0.0018	0.0004	0.0014	0.0010	0.0004
	100.0	20.0	80.0	59.1	20.9
2005-06	0.0018	0.0003	0.0015	0.0011	0.0003
	100.0	17.2	82.8	64.2	18.6

Source: Author's calculations