Determining Cut-off Points of Malnutrition of Indian Children: An Analysis by Developing New Growth Curves of Children's Nutritional Status for India using Cross Sectional Data

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Introduction:

Malnutrition has been increased over the period in developing countries. Half of the world's malnourished children are to be found in just three countries - Bangladesh, India and Pakistan. Child malnutrition rates in South Asian countries are higher than sub - Saharan Africa (Mehrotra, 2006). It commonly affects all groups in a community, but infants and young children are the most vulnerable because of their high nutritional requirements for growth and development. India has largest child development program in the world, yet progress on malnutrition is limited. States with the highest levels of malnutrition have the lowest levels of nutrition program funding. More in rural and SC/ST children are malnourished (Gragnolati *et al.*, 2005).India's primary policy response to child malnutrition, the Integrated Child Development Services (ICDS) program, is well-conceived and well-placed to address the major causes of child undernutrition in India.

Many studies have been done on child malnutrition relating it to child morbidity, child deaths and manpower and so on. In different researches some standard measures are used to identify the malnourished population. For individual applications in screening high risk children, cut-off points should be locally identified by taking into account: the population-specific prevalence and nature of malnutrition; the cut-off point below which children are shown to respond to specific interventions (de Onis, 2000). Most of the programs in India have used Indian Academy of pediatrics (IAP) and NCHS/WHO standards to classify children in different grades of nutrition. There is need to examine the use of different reference population in India for growth of children and scrutinize the actual malnourished population because if it is underestimated then a wide gap does matter of concern and raises even ethical consideration of depriving large number of severely malnourished children of the benefits of supplementary food.

In India, rich cross sectional data from three rounds of National Family and Health Survey (NFHS 1992-93, 1998-99, 2005-06) are available on anthropometric measures namely height and weight. This can be utilized to develop growth curve for children of India. Since, country like India where many more serious problems are there and many programs are implemented for human development but at the same time infrastructures are limited to fulfill all in efficient way so this will help us in identifying malnourished children with our own Indian standards. The present study is an effort in better way to represent children malnutrition in Indian context by

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developing New Growth curves using three rounds of NFHS data and observe the gap between WHO standards and New Growth curves obtained.

Review of literatures as a base to standard reference population for developing new Growth Curve:

Birth weight of children, age, nutritional awareness of mothers, their interest in the media and household income significantly affects the child's nutritional condition (Ekanayake et al., 2004). A study in Bangladesh makes known that the ratio of poorest to the richest indicates that stunting and underweight of the rural under-five children was almost two times higher than that of the richest children. This inequality in health situation of the children can be explained in terms of income inequality. It is expected that the findings will lead to consider alternative program strategies for the reduction of poor nutritional status of the children and their mothers (Giashuddin M S et al., 2005).

Many factors can cause malnutrition, most of which relate to poor diet or severe and repeated infections, particularly in underprivileged populations. Inadequate diet and disease, in turn, are closely linked to the general standard of living, the environmental conditions, and whether a population is able to meet its basic needs such as food, housing and health care (Blössner et al., 2005). Moreover, during the 1990s, urban-rural, inter-caste, male-female and inter- quintile inequalities in nutritional status widened.

Selection of Standard Reference Population for child growth curve:

Anthropometry is an important tool in the epidemiological assessment of the health and nutritional status of populations of children. Anthropometric values are compared across individual relation to a set of reference values. The choice of reference population to assess nutritional status has a significant impact on the proportion of children identified as being malnourished and, in turn, important programmatic implications for what to do about it (WHO, 1995). Following procedure has been adopted for selecting Indian standard reference population.

Based on review of literatures factors which influence the nutritional status of children are examined and all those children with the below characteristics were selected.

Child factor: Age of child, birth size(average and above average), birth interval(greater than two years), sex of child, infant feeding practices(exclusive breast feeding for 6 months, semisolid food along with breastfeeding for 6-9 months).
Maternal factor: Number of children(less than 5 children), non-smoking women.
Household factor: Sanitation, congestion, consumer durable indicators which are common in three rounds. For each round, Wealth Quintile (WQ) is computed by applying Principal Component Analysis (PCA). In the highest (10^{th}) quintile, classification of children for weight, and height were examined. Less than 5 percent children were found malnourished in the highest quintile. Hence it was decided to consider 10^{th} quintile children. Three rounds NFHS data were

merged using common wealth indicators in all rounds to calculate wealth quintiles. A common WQ has been obtained using PCA.

Data exclusions: At each age for boys and girls (Weight-for-age and Height-for-age) mean, median, standard deviation, skewness and kurtosis are calculated. To avoid the influence of unhealthy weights for length/height, observations falling above +3 SD and below -3 SD of the sample mean were excluded prior to constructing the standard.

Sample size: After exclusions of extreme cases, the total sample size for upper tenth WQ was 7679(4206 boys and 3473 girls). For some ages (age 36 months and above) number of cases was less than 30. In these cases, pooling of data has been made for sufficient sample size in each age (for Weight-for-age and Height-for-age) with its preceding and succeeding age data. It may be noted that for the development of growth curve, WHO used 6669 children (3450 b and 3219 g) and only 1487 children were from India.

Methodological consideration: distributional aspects

To construct attained growth curves, the distributional properties of the anthropometric measurements must be studied and centile estimates derived within and across ages. For the most common anthropometric indices knowledge from existing references can be used as a starting point. Methods based on distributional assumptions have been used widely for their ability to produce z-scores and estimate extreme centiles more accurately. This requires appropriate agreement between the data's distribution and the selected method's distributional assumptions. Distributions usually are characterized by summary statistics related to three moments: mean, standard deviation (or coefficient of variation (CV)) and skewness. However, the effect of the distribution's fourth moment, i.e. the kurtosis, is increasingly seen as possibly important in estimating extreme centiles. Attention was called to the difficulties of effectively modeling kurtosis through extrapolation given the sparse information usually available at the tails. Thus, methods adjusting for kurtosis are compared with methods that adjust only for the first three moments.

Transformed Age used: a power transform of (age)^power, where power is a value between –3 and 3. If the power is equal to zero it is a log transform. If the power is zero or a reciprocal of an even value, then age must be positive.

Choice of Distribution:

WHO (2006) used Box-Cox power exponential distribution after examining several methods. Hence, for India also it is decided to use the same distribution. The BCPE is a flexible distribution that offers the possibility to adjust for kurtosis, thus providing the framework necessary to test if fitting the distribution's fourth moment improves the estimation of extreme percentiles. It simplifies to the normal distribution when $\nu=1$(skewness) and $\tau=2$(kurtosis), and when $\nu\neq1$ and $\tau=2$, the distribution is the same as the Box-Cox normal (Location, Median and Scale(LMS) method's distribution). The BCPE is defined by a power transformation (or Box-

Cox transformation) Y^{υ} having a shifted and scaled (truncated) power exponential (or Box-Tiao) distribution with parameter τ (Rigby and Stasinopoulos, 2004). Apart from other theoretical advantages, the BCPE presents as good as or better goodness-of-fit than the modulus-exponential-normal or the other distributions.

Let *Y be* a positive random variable having a Box-Cox power exponential distribution, denoted by *BCPE* (μ, σ, υ, ζ), defined through the transformed random variable *Z* given by

$$Z = \begin{cases} 1/ \sigma \upsilon \, [(y/ \mu)^{\upsilon} -1], & \text{if } \upsilon \neq 0 \\ 1/ \sigma \log(y/ \mu), & \text{if } \upsilon = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1) \end{cases}$$

for $0 < Y < 1$ where $\mu > 0$ and $\sigma > 0$, and where the random variable *Z* is assumed to follow a standard power exponential distribution with power parameter, $\zeta > 0$, treated as a continuous parameter. [The parameterization (1) was used by Cole and Green (1997) who assumed a standard normal distribution for *Z*.]The probability density function of *Z*, a standard power exponential variable, is given by

$$f_Z(z) = \zeta /[c2(1+1= \zeta) \, !(1/ \zeta)] \, \exp(-0.5|z/c|^{\zeta})\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

for $- \infty < z < +\infty$ and $\zeta > 0$, where $c^2 = 2^{-2}/ \zeta \, !(1/ \zeta)[! \, (3/ \zeta)]^{-1}$. This parameterization, used by Nelson (1991), ensures that *Z* has mean 0 and standard deviation 1 for all $\zeta > 0$. Note that $\zeta = 1$ and $\zeta = 2$ correspond to the Laplace (i.e. two sided exponential) and normal distributions respectively, while the uniform distribution is the limiting distribution as $\zeta \rightarrow \infty$ [Strictly, the exact distribution of *Z* in (1) is a truncated standard power exponential distribution.] From (1), the probability density function of *Y*, a *BCPE* (μ, σ, υ, ζ) random variable, is given by

$$fY(y) = fZ(z)|dz/dy| = y^{\upsilon-1}/\mu^{\upsilon} \sigma f(z)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Choice of smoothing technique

Using the GAMLSS in R software, cubic spline technique is used for smoothing length/height-for-age and weight-for-age curves. A number of combinations are tried among the different parameter curves, considering the Akaike Information Criterion (Akaike, 1974), *AIC*, defined as:

$$AIC = -2L-2p$$

where *L* is the maximized likelihood and *p* is the number of parameters (or the total number of degrees of freedom). According to this criterion, the best model is the one with the smallest AIC value. The cubic spline smoothing technique offered more flexibility than fractional polynomials in all cases.

Choice of method for constructing the curves:

In summary, the BCPE method, with curve smoothing by cubic splines, is selected as the approach for constructing the growth curves. Modeling the mean (or median) of the growth variable under consideration as well as other parameters of its distribution that determine scale and shape. The simplified notation to describe a particular model within the class of the BCPE method is:

$$BCPE(x=x, df(\mu)=n1, df(\sigma)=n2, df(\nu)=n3, df(\tau)=n4),$$

where $df(\cdot)$ are the degrees of freedom for the cubic splines smoothing the respective parameter curve and x is age (or transformed age) or length/height. Note that when $df(\cdot)=1$, the smoothing function reduces to a constant and when $df(\cdot)=2$, it reduces to a linear function. *Dr Huiqi Pan and Professor Tim J. Cole (2004)* provided the software *LMS light and pro*, which offers the fitting of growth curves using the LMS method in interactive way, including some of the available diagnostics for choosing the best set of degrees of freedom for the cubic splines and goodness-of-fit statistics.

Selecting the best model using GAIC value:
Models are grouped in classes according to the parameters to be modelled. The alternative to modelling parameters was to fix them, e.g. ν=1 or τ=2. The criteria used to choose among models within the same class were the *AIC* and the generalized version of it with penalty equal to 3 (*GAIC (3)*) as defined in Rigby and Stasinopoulos (2004):

$$GAIC = -2L-3p$$

where L is the maximized likelihood and p is the number of parameters (or the total number of degrees of freedom). While the use of the *AIC* enhances the fitting of local trends, smoother curves are obtained when the model's choice is based on the *GAIC (3)* criterion. Consistency in the use of these two criteria was attempted across all indicators. For selecting the best combination of df(μ) and df(σ), both criteria were used in parallel. In cases of disagreement, *AIC* is used to select df(μ) and *GAIC(3)* to select df(σ), overall favouring the options which offered a good compromise between keeping estimates close to the empirical values and producing smooth curves. Only *GAIC(3)* values are examined to select df(ν) and.

Model Fitting

Model used: $BCPE(x=age^{\lambda}, df(\mu)=n1, df(\sigma)=n2, df(\nu)=n3, \tau=2)$

[a] Age transformation power.
[b] Degrees of freedom for the cubic splines fitting the median (μ).
[c] Degrees of freedom for the cubic splines fitting the coefficient of variation (σ).
[d] Degrees of freedom for the cubic splines fitting the Box-Cox transformation power (ν).
[e] Parameter related to the kurtosis fixed (τ=2).
[f] ν=1: Normal distribution.

In Model fitting, the fit of the current model as measured by the Global deviance. This is hard to interpret on its own. Change in degree of freedom (df) and the corresponding change in deviance has been adopted when model changes. The change in deviance is approximately distributed as Chi-square with the number of df changed. This provides a simple way to judge the importance of changes to the model. In theory a change of 4 units of deviance for 1 df is just significant at the 5% level. In practice the change in deviance needs to be appreciably larger, say 8 or more, before it becomes important. With very large samples (n > 10,000) large changes in deviance (>20) may correspond to tiny and trivial changes in the shapes of the fitted curves.

Choosing Degree of Freedom (df): The order for choosing df values

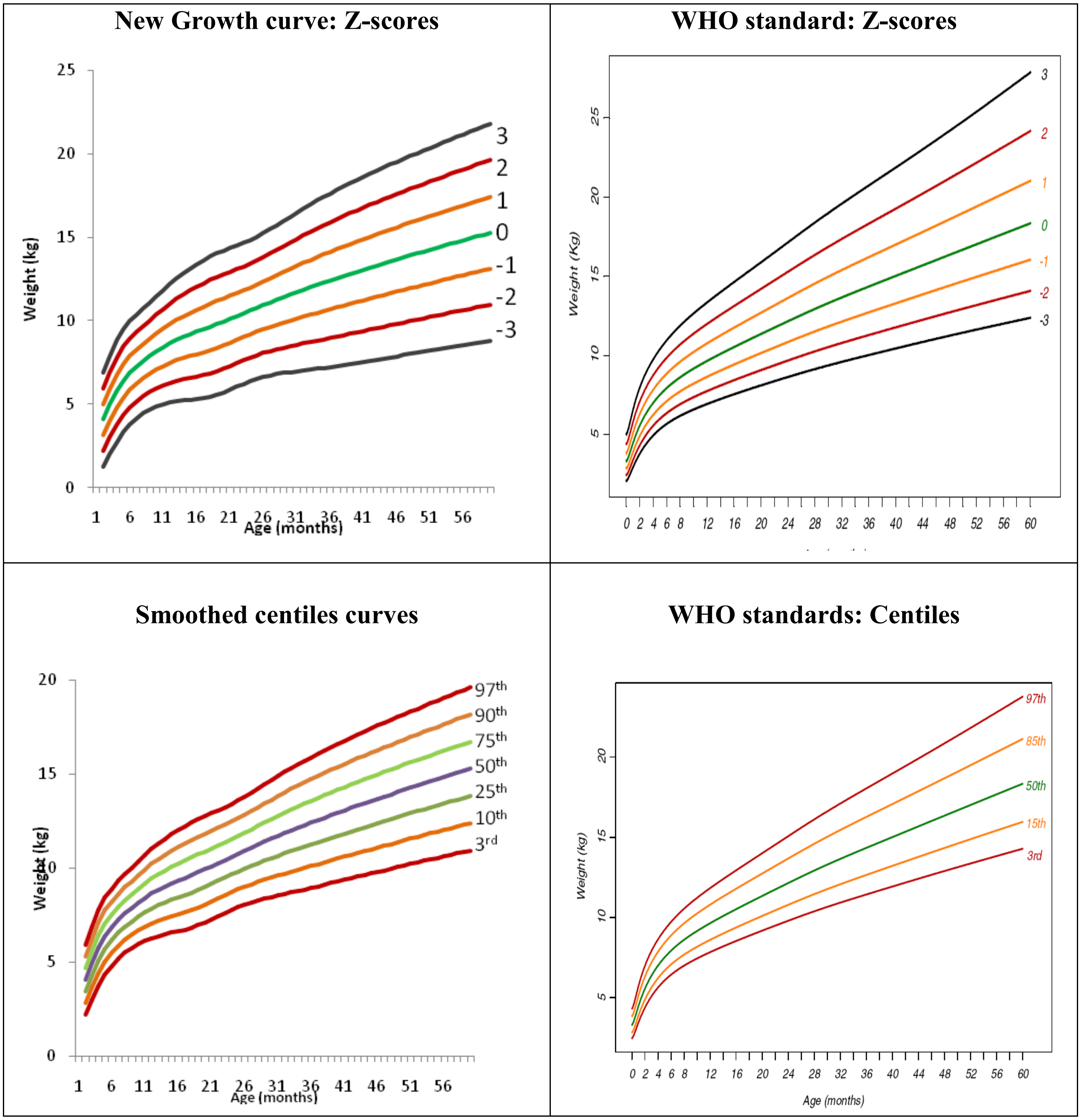
Choose df values for L, M and S in the following order:

i) Optimize the M curve by increasing and/or decreasing the df by 1 until the change in deviance is small. For small datasets (e.g. n < 500) the default df of 5 may be adequate. For larger datasets (n > 10,000) the df may reach 15 or more.
ii) Optimize the S curve. In many cases 3 df will be sufficient, though df up to 10 or more may be needed for larger datasets.
iii) Optimize the L curve. 3 df may be too large in many cases, a value of 0, i.e. no skewness adjustment, then 1, which is a constant adjustment at all ages. In general df for M> S> L.

Results:

After birth, weight showed a good fit (fig.1 and fig.2) at all ages for both girls and boys. Median Z-score of weight of Indian children had slight low values at each age as WHO standard while range of Z=2, 3 is smaller than WHO growth curves due to smaller SD. However, Z-scores by age 12 months are more similar to WHO 2006 standard and later on z-scores showed little lower values slow declined towards the WHO median. Therefore children aged above 12 months were considerably more likely to be classified as underweighted by WHO standard as compared to New Growth curve.

Figure 1.Weight-for-age (boys)



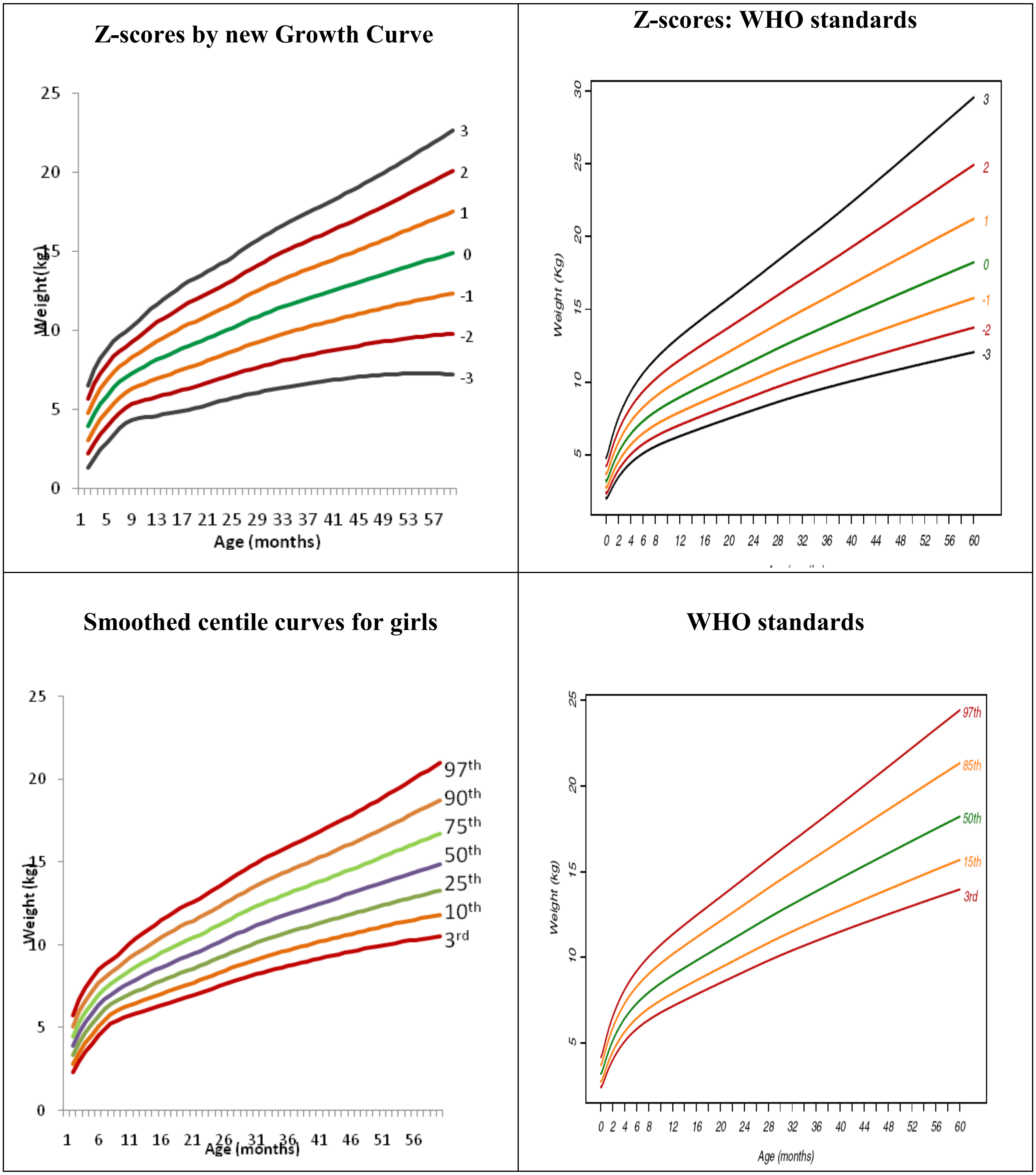
New Growth curve: Z-scores

WHO standard: Z-scores

Smoothed centiles curves

WHO standards: Centiles

Figure 2.Weight-for-age (Girls)



Z-scores by new Growth Curve

Z-scores: WHO standards

Smoothed centile curves for girls

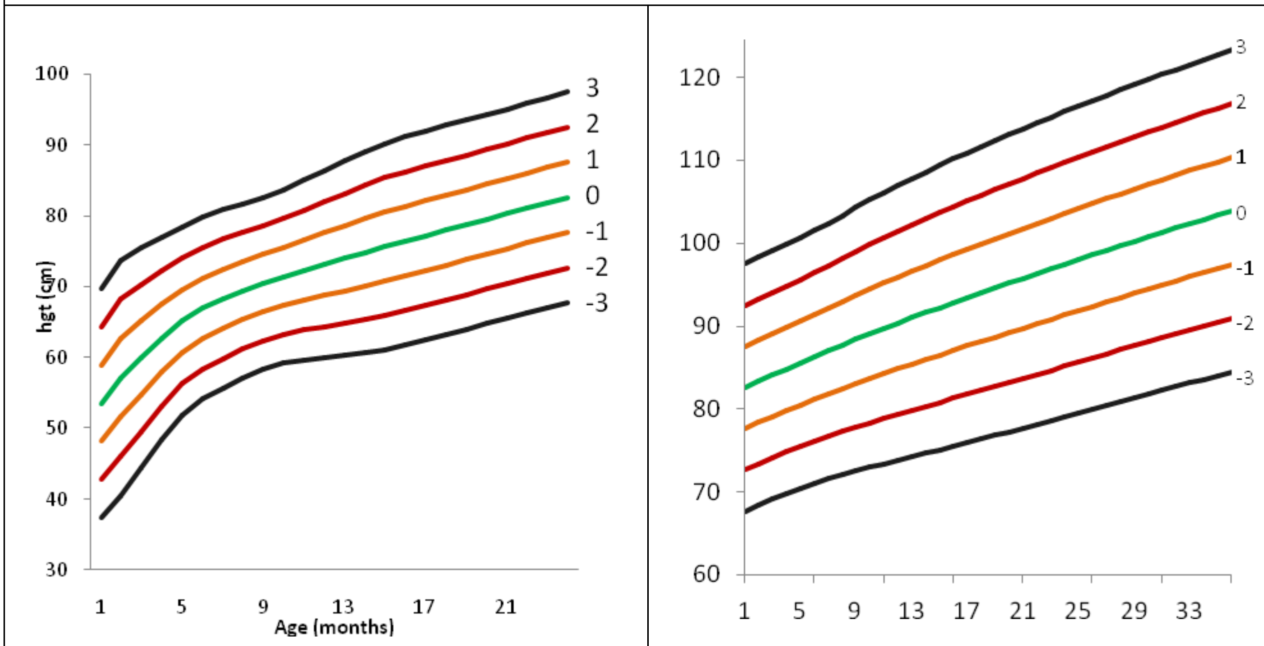
WHO standards

Figure 3.Height-for-age (boys)

Z-scores by new developed growth curve

0-24 months

24-60 months



Z-scores by WHO

WHO standards

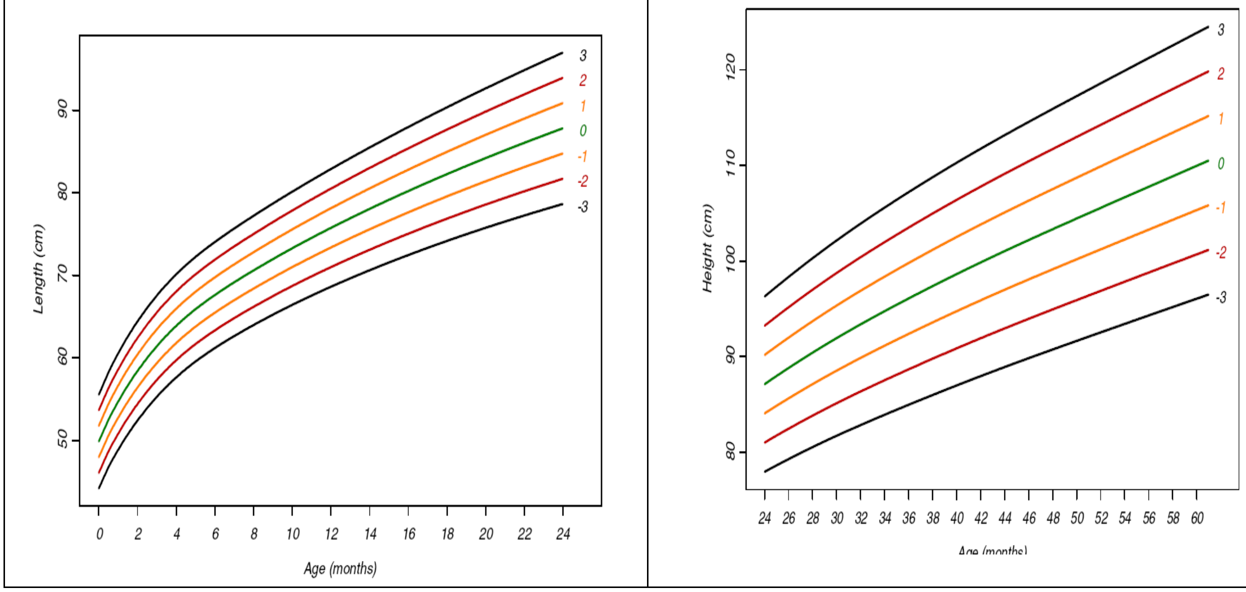
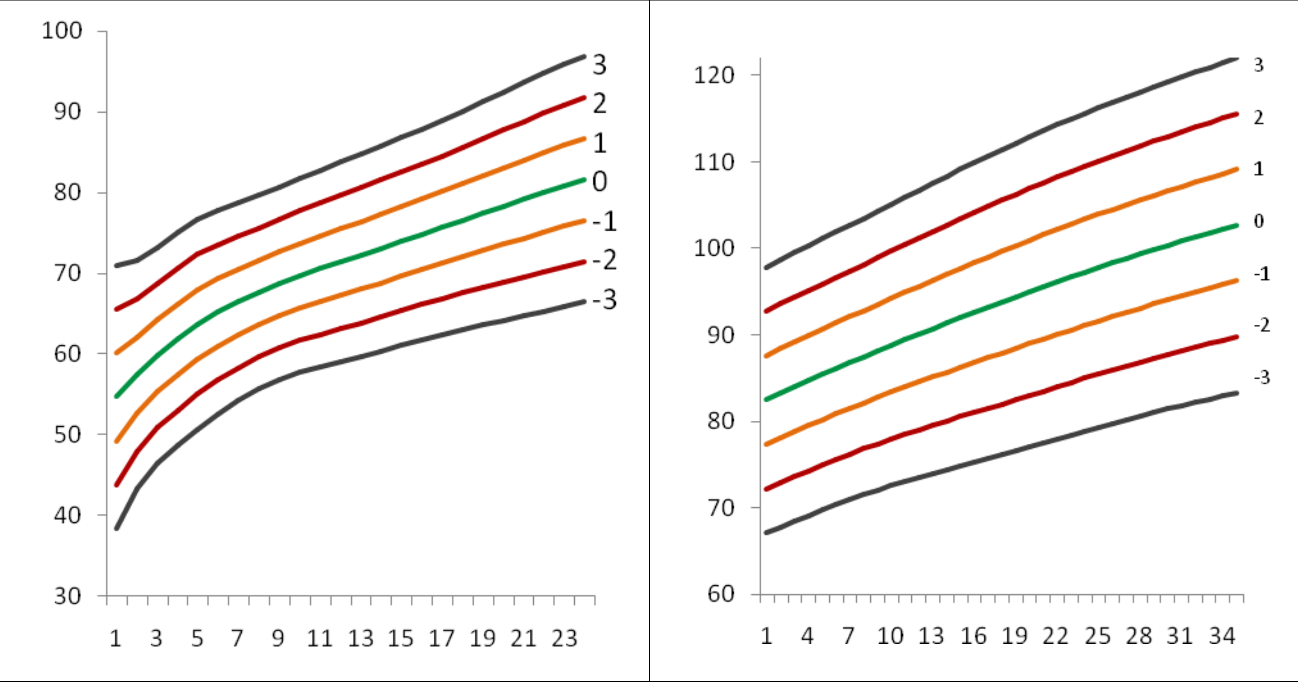
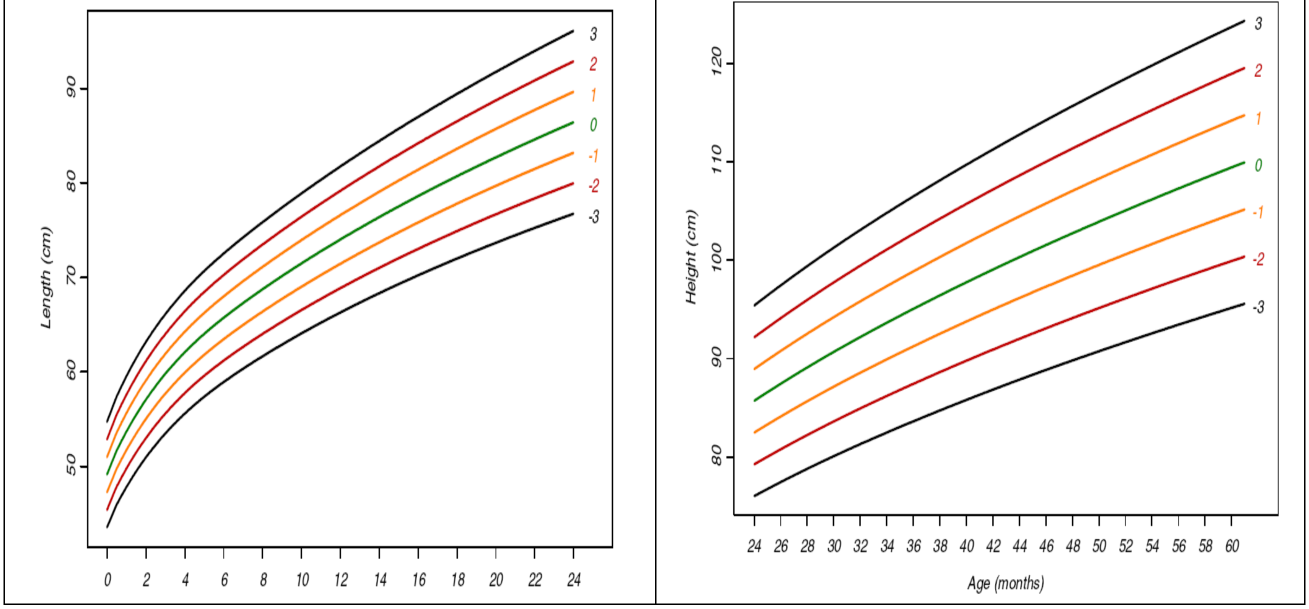


Figure 4.Height-for-age (Girls): Z-scores



New growth Curve: 0-24 months

24-60 months



WHO Z-score

WHO Z-scores

Is has been observed that after birth, in initial ages by 6 months, New growth curves (range of Z=2, 3) is quite expanded (fig.3 and fig.4) from median height because of larger SD in later ages New curves have good fit for both girls and boys. Indian children had relatively low mean z-scores for height at each age as compared with the WHO standard while pace of growth in height is almost same as WHO standard at each age. Therefore children were considerably more likely to be classified as stunted by WHO standard as compared to New Growth curve.

Summary and conclusion:

Compared with the WHO standard, New curves have almost similar birth weights (mean z-scores and percentiles) and lower birth height/lengths. After age 12 months, the risk of being classified as underweight is considerably higher and after age 6 months, stunted are higher according to the WHO standard as compared to the New Growth Reference .Adoption of the WHO 2006 Growth Charts would set a markedly higher standard of weight gain beyond the age of 12 months and higher values of height growth for Indian children and could support efforts to avoid future childhood malnourishment. However, the WHO standard is not more representative of size at birth in the India. However, the WHO standard is not more representative of size at birth in the India.

The WHO 2006 Child Growth Standard embodies a number of novel and admirable principles, with the aim of promoting optimal infant and childhood growth. In consequence, the WHO feels able to publish a standard for optimal growth of children and good for comparison between countries. Since, our main concern is on children under age five where among them infant mortality is high and malnutrition may be one of the reasons for this mortality. One may think about the actual picture of malnourished population because country like India where population is too large and resources are limited. Implementing program for such population is hard to identify and allocate resources in judiciary and optimum way and need to develop standard at National level. However, WHO standard is not more representative of size of children in the India.

Limitations of the study:

Zero age group children are not included here because of small sample size (<30). There may be some improper measurements (lying position) and some age reporting biasness in early age of children can be adjusted further so that to achieve good pattern of growth. Height and length could not be adjusted (under two age) for lying and standing position in this cross sectional data which is secondary in nature. Some cross check can be done at some extent using longitudinal data and hospital based data as well.

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