Comparison of Nutritional Status of Under-Five Indian Children (NFHS 4 Data) Using WHO 2006 Charts and 2019 Indian Synthetic Charts

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Abstract

Introduction: There is a growing body of evidence against using World Health Organization (WHO) charts for developing nations. Our objectives were: 1) To compare nutritional status of <5-year-old Indian children using WHO charts and synthetic Indian charts (SC) 2019. 2) To study nutritional status across wealth index categories. 3) To study nutritional status of predominantly breast-fed infants <6 months of age using both charts. **Materials and Methods:** Data from 4th National Family Health Survey ($n \sim 236117$, 0--59-month-old children) were used for assessing nutritional status using the WHO charts and SC. Z-scores were calculated for length/height, weight, and weight-for-height (WAZ) using both charts. Children were classified into degrees of malnutrition using appropriate cutoffs. **Results:** Stunting, wasting, and underweight were significantly higher using WHO charts. The prevalence of stunting (height for age) and wasting (WHZ) changed from high to medium and critical to poor when the reference changed from WHO to SC. All Z-scores showed an improving trend with increasing wealth index. On SC, almost all WHZ (wasting) from the richest to poorer were >-0.5 (clinically significant), whereas on WHO charts all wealth classes had WHZ <-0.5. For children under the age of 6 months, WHZ from richest to poorest was between -0.97 and -0.89 by WHO and 0.27 and 0.38 by SC. **Conclusions:** Use of Indian synthetic growth charts for growth monitoring of under-five children may be more appropriate; infants under 6 months and children from well off families performed well on these charts.

Keywords: Indian, NFHS, nutrition, synthetic growth charts, under five, WHO charts

INTRODUCTION

The World Health Organization (WHO) 2006 growth charts have been used widely as a single global standard to study nutritional status of under-five children. While these charts are very useful for across globe comparison of children's growth and nutrition, they have been criticized, as these charts are more "aspirational" than realistic for a large part of the developing world. Many symmetrically small normal children are misclassified as stunted, wasted, or underweight using these charts; there is a growing body of evidence against using WHO charts in many countries.[1,2] Further, the WHO growth curves seem to differ considerably from the growth patterns of many populations especially in the first 6 months of life. Most breast-fed babies in Europe are much heavier and longer than the WHO charts while they are lighter and shorter in Asian countries.[3]

Studies have recommended that in countries where local/national charts are available and where the growth patterns of children differ from the WHO charts, it may be more appropriate to use local references to avoid unnecessary labeling of normal children as stunted, underweight, or wasted. On the other hand, the argument against references based on children from developing countries is that these references

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may classify poorly nourished children as normal. To avoid the aforementioned, references are normally designed on children from the middle or upper socio-economic class, that is, on children who have the best available nutrition and healthcare.

A more suitable method, however, may be to construct growth references using the novel method of synthetic anthropometry that takes into consideration local growth parameters and global trends.[4] Synthetic growth charts have recently been adopted as national references by some countries such as Indonesia, Romania, and Germany as they are believed to be more appropriate than the WHO charts for that specific country.[5-7] Synthetic growth references for Indian children from 0 to 18 years have also recently been published in 2019.[8] In a study from Indonesia, it was observed that Indonesian synthetic growth references were more suited for Indonesian babies as compared to WHO charts.[9]

Taken together, the WHO charts are likely to be more aspirational and synthetic growth references more appropriate for assessment of nutritional status of under-five children in a developing country such as India. Thus, our aim was to assess the applicability of WHO charts versus synthetic Indian growth references for the assessment of nutritional status of Indian children. We used data on children under five years from the National Family Health Survey round 4 (NFHS 4 data) which is a large-scale, multi-round survey conducted in a representative sample of households throughout India.[10] Apart from assessing the prevalence of underweight, stunting, and wasting using the two charts/references for all under 5-year-old children as a group, we separately assessed the same in infants under 6 months and in different socioeconomic classes (as judged by the wealth index). Our specific objectives thus were: 1) To compare nutritional status of under-5-year-old Indian children using WHO 2006 charts and synthetic Indian growth references 2019. 2) To study nutritional status using WHO charts and synthetic references as per wealth index categories. 3) To study nutritional status of a subgroup of predominantly breast-fed infants under 6 months of age using the two charts.

MATERIALS AND METHODS

The Govt. of India completed the fourth national family health survey (NFHS 4) in 2015--16 and data are available for analysis from Demographic and Health Survey Program (DHS), USA.[11] The NFHS 4 is a comprehensive survey containing over 1,300 demographic, socioeconomic, and anthropometric variables including children's birth weight, weight, and height/length from 0 to 59 months of age. We used these data for comparing nutritional status of Indian children using two different scales viz. WHO charts and recently published Indian synthetic growth references 2019. Since deidentified data were used and secondary data analyses were performed, a waiver was obtained from the institutional ethics committee (2 March 2020).

A total of 259,627 records (135,102 boys (52%)) of under-five children's anthropometry were available from the NFHS 4 survey.

Standard deviation scores (Z-scores) were calculated for length/height for age, weight for age, and weight-for-height using WHO Anthro software for WHO charts and using Lambda, Mu, and Sigma (LMS) values for Indian synthetic growth references.[8] Also, percentiles for height, weight, and weight-for-length for the NFHS 4 data were generated and smoothed using PSPP Gnu software version 1.2 statistical package. As per WHO recommendations, records likely to be erroneous (based on WHO Z-scores) were removed as illustrated in the flow diagram [Figure 1]. The final analysis was thus performed on 236,117 records for weight, 232,697 for length/height and 229,324 for weight-for-height, and 190,769 (100,304 boys) for birth weight.

Statistical analysis

The statistical analysis was performed using IBM SPSS 26 (version 26.0, IBM Corp, Armonk, NY, USA). Significance was set at $P < 0.05$. The percentiles for height, weight, and weight-for-length for the NFHS were compared with WHO and synthetic charts.

For weight, children were classified as underweight, severe underweight, normal and overweight based on Z-scores of below -2, below -3, between -2 and +2, and above +2, respectively, for the standard/reference used; for height they were classified as stunted below -2, severely stunted below -3, normal between -2 and +2, and tall above +2 Z-scores. Similarly, for weight-for-height, children were classified as wasted below -2, severely wasted below -3, normal between -2 and +2, and overweight above +2 Z-score. WHO categorizes the prevalence of malnutrition in a population as follows: For underweight; <10% low, 10–19% medium, 20--29% high and >=30% very high, for stunting; <20% low, 20--29% medium, 30--39% high and >=40% very high, for wasting < 5% acceptable, 5--9% poor, 10--14% serious, and >=15% critical.[12] These categories were used to compare the prevalence of malnutrition in the NFHS 4 data as per WHO vs Synthetic references. Paired *t*-test was used to compare differences between mean Z-scores for height for age, weight for height, and weight for age derived from the
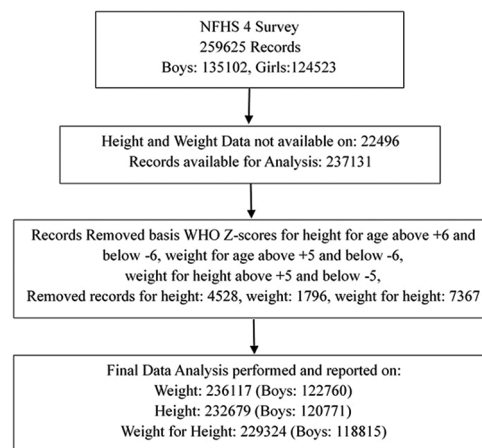
Figure 1: Flow Diagram of records excluded and included in the study

WHO and synthetic references. One-way ANOVA was used for assessing significance of differences between Z-scores of height for age, weight for height, and weight for age between wealth categories. McNemar's test of proportions was used to test the significance in difference between the proportions of stunted, underweight, and wasted as classified by the WHO and Synthetic reference data.

RESULTS

The mean age of the children was 29.7 ± 17.1 months (similar in boys and girls, $P > 0.1$). Table 1 illustrates comparison of growth parameters between WHO charts and synthetic Indian references for height, weight, and weight-for-height for 0-5-year-old children. It was observed that the prevalence of stunting (height for age) and wasting (weight-for-height) changed from high to medium (height for age: 38% to 27%) and critical to poor (weight for height: 18% to 9%) when the assessment reference changed from WHO to synthetic charts. Stunting, wasting, and underweight were significantly higher (Z-scores and percentages) when using WHO charts versus synthetic references [Table 1].

As per the wealth index, percentage of children in poorest, poorer, middle, richer, and richest classes were 24, 22, 20, 19, and 14, respectively. Table 2 illustrates the comparison of growth parameters as per the wealth index; data for infants under 6 months are presented separately. For both WHO charts and synthetic references, Z-scores on almost all parameters showed a significantly improving trend with increasing wealth index ($P < 0.05$). On synthetic references all weight-for-height Z-scores (wasting) from the richest to poorer were <-0.5 Z-score except the poorest which was -0.49, that is, almost -0.5 (clinically significant),[13,14] whereas on WHO charts, all wealth classes had weight for height Z-scores well below -0.5 (clinically significant). For children under the age of 6 months weight-for-height Z-scores from richest to poorest were between -0.97 and -0.89 on WHO charts, whereas for the synthetic references these were all positive from 0.27 to 0.38.

On WHO charts, the mean Z-score for wasting was -0.84 for under five and -0.91 for under 6 months, both below -0.5 SD, whereas for synthetic references mean Z-score for wasting was -0.33 for under five and +0.35 for under 6 months.

The mean birth weight for boys and girls was 2.87 ± 0.57 Kg and 2.8 ± 0.55 Kg, respectively. Mean birth weight for girls in the poorest was 2.74 ± 0.55 kg, poorer was 2.78 ± 0.56 Kg, middle was 2.80 ± 0.56 Kg, richer was 2.83 ± 0.55 Kg and richest was 2.87 ± 0.54 Kg while in boys it was 2.81 ± 0.58 Kg for poorest, 2.84 ± 0.58 Kg for poorer, 2.86 ± 0.58 Kg for middle, 2.90 ± 0.57 Kg for richer and 2.93 ± 0.56 Kg for the richest (all means significantly different than each other, $P < 0.05$).

To assess the whole group differences between NFHS4 data, synthetic references and WHO charts we computed percentiles for height, weight on NFHS 4 data. Comparison of NFHS 3rd, 50th, and 97th percentiles for length/height for age for both boys and girls are depicted in Figure 2. The 50th percentile of the NFHS height for age corresponded to the WHO 3rd percentile

Table 1: Growth parameters (Mean Z-scores (SD)), percentage and category of malnutrition using WHO vs Synthetic charts in 0-5 year-old children

Parameter	WHO Z-scores	WHO % and Category	Synthetic Z-scores	Synthetic % and Category
Height for age (Stunting) *n*=232697	-1.42 (1.78)*	38%*, High	-1.10 (1.55)	27%, Medium
Weight for height (Wasting) *n*=229324	-0.84 (1.41)*	18%*, Critical	-0.33 (1.21)	9%, Poor
Weight for age (Underweight) *n*=236117	-1.54 (1.32)*	35%*, Very high	-1.42 (1.57)	35%, Very high

*Mean WHO and Synthetic Z-scores and percentages are significantly different ($P<0.001$)

Table 2: Wealth index-wise comparison of weight, height, weight-for-height Z-scores using WHO vs Synthetic references (Mean (SD))

Wealth Index	WHO WAZ	WHO HAZ	WHO WHZ	SYN WAZ	SYN HAZ	SYN WHZ
Under 5 years						
Poorest (*n* 56662)	-1.81 (1.35)	-1.71 (1.85)	-0.94 (1.47)	-1.74 (1.61)	-1.36 (1.62)	-0.49 (1.4)
Poorer (*n* 52021)	-1.66 (1.29)	-1.56 (1.78)	-0.88 (1.43)	-1.56 (1.54)	-1.22 (1.55)	-0.43 (1.36)
Middle (*n* 48396)	-1.53 (1.28)	-1.44 (1.73)	-0.82 (1.40)	-1.42 (1.53)	-1.12 (1.51)	-0.38 (1.32)
Richer (*n* 44348)	-1.38 (1.26)	-1.25 (1.68)	-0.76 (1.41)	-1.24 (1.5)	-0.95 (1.46)	-0.33 (1.33)
Richest (*n* 34690)	-1.1 (1.31)	-0.92 (1.69)	-0.64 (1.46)	-0.93 (1.54)	-0.66 (1.47)	-0.25 (1.38)
Under 6 months						
Poorest (*n*=5023)	-1.35 (1.64)	-0.61 (2.24)	-0.91 (1.92)	-0.24 (1.65)	-0.08 (1.92)	0.32 (1.9)
Poorer (*n*=4756)	-1.24 (1.56)	-0.51 (2.16)	-0.91 (1.86)	-0.14 (1.58)	0.01 (1.85)	0.37 (1.81)
Middle (*n*=4510)	-1.16 (1.56)	-0.44 (2.08)	-0.89 (1.84)	-0.06 (1.59)	0.06 (1.78)	0.38 (1.73)
Richer (*n*=4108)	-1.12 (1.52)	-0.34 (2.06)	-0.89 (1.82)	-0.02 (1.55)	0.16 (1.76)	0.38 (1.8)
Richest (*n*=3236)	-1.04 (1.54)	-0.14 (2.1)	-0.97 (1.86)	0.06 (1.57)	0.33 (1.81)	0.27 (1.79)

WAZ: Weight for Age Z-score; HAZ: Height for Age Z-score, WHZ: Weight for Height Z-score; SYN: Synthetic Growth Charts; *All differences are highly significant between Richest to poorest and between WHO and synthetic charts
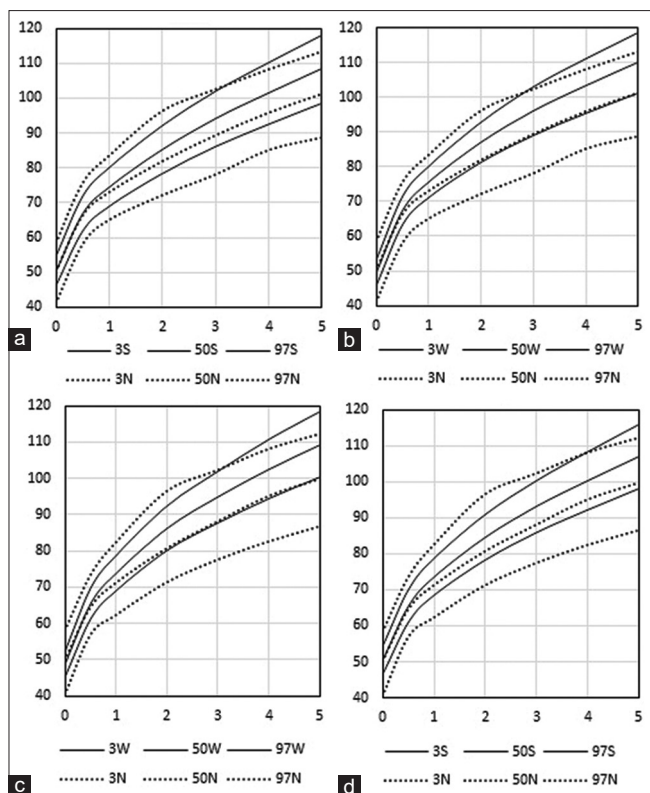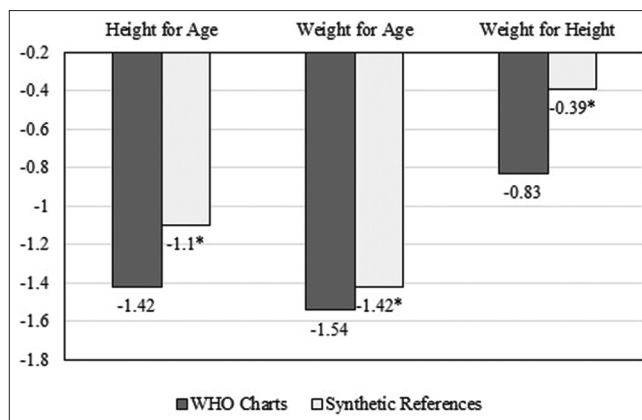
Figure 2: Comparison of NFHS Height percentiles with synthetic reference percentiles (a) and WHO percentiles (b) in Boys and Girls (c and d). Footnote: (a) comparison of NFHS boys percentiles with WHO percentiles; (b) comparison of NFHS boys percentiles with Synthetic reference percentiles; (c) comparison of NFHS girls percentiles with WHO percentiles; (d) comparison of NFHS girls percentiles with Synthetic reference percentiles; W: WHO percentile; N: NFHS percentile, S: Synthetic reference percentiles. Dotted lines depict the NFHS percentiles

Figure 3: Comparison of Z-scores using WHO and Synthetic References. *Significant difference between the Who and Synthetic Reference Z-Scores

while the difference was less marked when compared with the synthetic references (both in boys and girls). Similar observations were made for weight and weight-for-length parameters (data not presented). Figure 3 shows comparison of mean Z-scores for various growth parameters on WHO versus synthetic charts. The mean scores were significantly lower ($P < 0.05$) for all parameters using WHO charts, although the differences were less pronounced for the weight for age.

Further, to assess the agreement between the WHO charts and synthetic references, Bland-Altman plot analysis was carried out [Figure 4]. The agreement between the two references was better for HAZ than WAZ and WHZ. The references showed low agreement at both the ends of the mean difference. The mean of difference between the WHO and Synthetic HAZ was -0.32 ± 0.29, WAZ was -0.11 ± 0.42 and for WHZ it was -0.51 ± 0.51.

DISCUSSION

In this study, we have compared performance of Indian children from the NFHS 4 (2015-16) on two scales, viz. WHO 2006 growth charts and recently published Indian synthetic references. We observed that Indian under-five children had a

higher prevalence of stunting, underweight, and wasting when assessed using WHO charts, whereas they performed better on the synthetic references. Using WHO charts, children from the NFHS 4 data were classified as very high for underweight, high for stunting and critical for wasting, whereas for synthetic references, the same was high for underweight, medium for stunting and poor for wasting. Also, there was relative lack of agreement between the WHO charts and synthetic references as assessed by Bland-Altman plots. Further, the richest population of the NFHS 4 data was close to the mean of synthetic references. On the synthetic references, infants thrived well in the first 6 months with mean Z-scores for all three parameters being very close to 0 (-0.09 for weight, 0.07 for height, and 0.35 for weight-for-height), a difference that is clinically insignificant suggesting normal growth. However, on the WHO charts all parameters for infants less than 6 months were much lower (mean Z-score: -1.2 for weight, -0.43 for height, and -0.91 for weight-for-height), suggesting clinically significant malnutrition.

Indian synthetic growth references were produced using a novel method that constructs country specific growth charts based on global trends. The method used anthropometric means of local (here, Indian) middle and upper-middle socioeconomic class population at key ages and then using global regression equations, means for height, weight, and weight-for-height were constructed for all the remaining ages. The details of this method are published elsewhere.[8] The WHO growth charts describe how children should grow rather than describing how they grow. The strength of WHO charts is that they depict breast feeding as the biological norm and are useful for global assessment of under-five children's growth. However, when using WHO charts, many studies have raised doubts about their suitability to detect at-risk children and recommended the use of local (ethnic-specific or country-specific) references instead of the WHO charts.[15,16]

WHO charts for weight and for weight-for-height are higher than many national references including the CDC, Netherlands, and Euro-growth charts especially in the first 6 months of
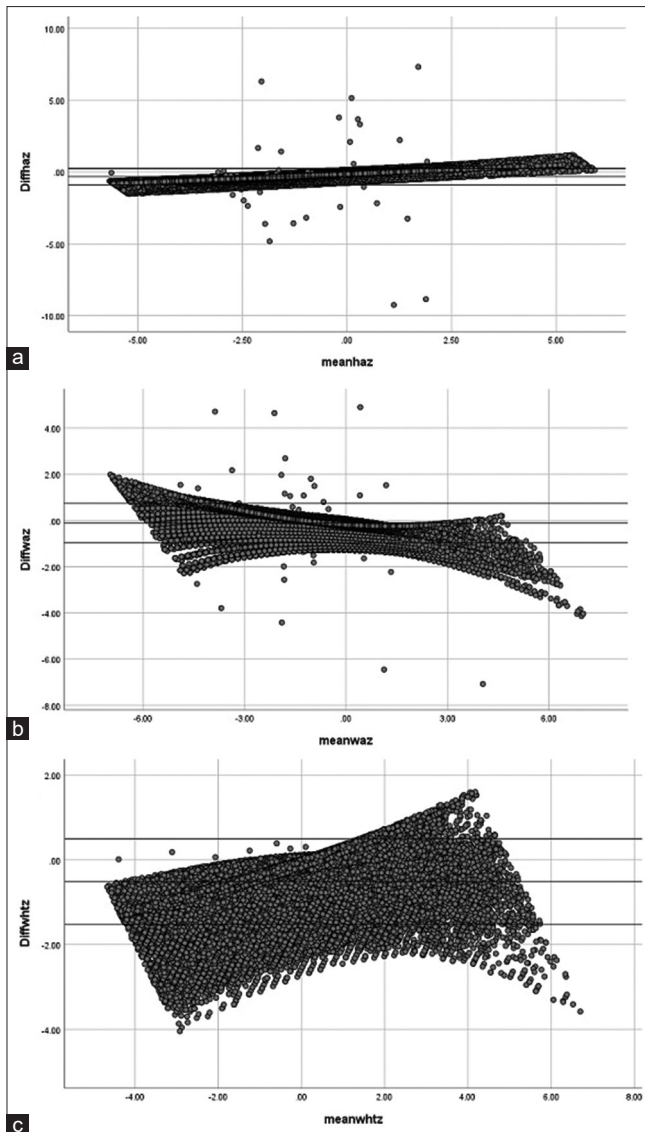
Figure 4: Bland Altman Plot for HAZ (a), WAZ (b) and WHZ (c)

life.[15,16] Our observations of lower mean weight-for-height Z-scores using WHO versus synthetic charts are in line with these studies. In a recent study comparing growth parameters of south Asian, Asian Indian, and Dutch children living in the Netherlands, authors report that WHO charts mis-classify in the first 6 months of life; underweight and wasting were considerably overestimated in Asian Indian children living in Netherlands for generations. This study recommends ethnic-specific growth references for populations whose growth is very different to WHO curves such as the Asian Indian children.[17]

Comparison of growth parameters based on the wealth index shows a clear drop in Z-scores on all parameters from the richest to the poorest, richest performing better on all parameters both in WHO charts and synthetic references. However, on the weight-for-height parameter, the poorest was the only group that reached the level of clinical significance (-0.5 Z-score) on the synthetic references but on WHO charts all socioeconomic

classes were below -0.5 Z-score indicating all classes, even the richest in NFHS 4 data, were significantly malnourished, an observation that is likely to be incorrect. Thus, the synthetic references seem to be able to make a distinction between clinically significant nutritional deficit versus clinically acceptable deficit unlike the WHO charts.

A recent systematic review of growth parameters from 54 nations on WHO charts suggests that populations with small average body sizes would not fit well into the WHO charts and these groups would presumably require their own charts for optimal analysis of growth.[3] Also, Indian children were found to be some of the shortest in the world on the WHO charts with height deficits much lower than the clinically significant -0.5 SD. This systematic review also suggests that in populations that are shorter, weight must be interpreted carefully on the WHO charts and weight for height should be given more weightage. WHO charts that fit poorly with a population may pose barriers to diagnose correctly when a problem exists, create unnecessary stress when there is no problem, and increase strain on an overtaxed healthcare system.

Under five mortality rate of a nation reflects the social, economic, and environmental conditions and health care in which children (and others in society) live. Also, reduction in the under-five mortality of any nation is considered to reflect overall improvement in living conditions, socioeconomic status and health care services. With reduced under-five mortality, it is logical to expect improvement in the nutritional status of children. However, when children are assessed on WHO 2006 growth charts, this does not seem to reflect in many countries which have shown a significant drop in the under-five mortality rate over last couple of decades for example, in Bangladesh, the under-five mortality has dropped from 92 to 46 from year 2000 to 2014 but the rate of stunting as per WHO charts has changed marginally from 15% to 14%. Similarly, in India, the under-five mortality has dropped from 91 to 43 from year 2000 to 2015 but the rate of wasting as per WHO charts has remained unchanged (from 17.1 to 20%) even when there is economic improvement as reflected in the per capita income of $443 in year 2000 to $1606 in the year 2015.[18,19] This seems true of many south Asian countries perhaps because the growth pattern of these children is not as per the WHO charts and hence there is an inappropriate classification of children as being stunted, underweight, or wasted.

The strength of our study is that we have focused on the critical under 5 years age group and used the large NFHS dataset that provides information on growth parameters for children from each state and union territory of India. Data on anthropometric parameters of around 200,000 children were analyzed. However, the data are cross-sectional and we did not have future outcomes to correlate with study results.

To conclude, our study suggests that use of Indian synthetic growth references for monitoring of growth of under-five children may be more appropriate; infants under 6 months and children from well off families performed well on these

charts. Use of appropriate charts will avoid misclassification of children as underweight, stunted, and wasted and thus will help to reduce the strain on healthcare systems.

Conflicts of interest
There are no conflicts of interest.

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