Review Article

# Growth charts: A diagnostic tool

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## ABSTRACT

**Context:** Assessment of growth by objective anthropometric methods is crucial in child care. India is in a phase of nutrition transition and thus it is vital to update growth references regularly. **Objective:** To review growth standards and references for assessment of physical growth of Indian children for clinical use and research purposes. **Materials and Methods:** Basics of growth charts and importance of anthropometric measurements are described. A comparison between growth standards and references is provided. Further, Indian growth reference curves based on the data collected by Agarwal *et al.* and adopted by the Indian Academy of Pediatrics, World Health Organization growth standards for children under the age of 5 years (2006) and contemporary Indian growth references published on apparently healthy affluent Indian children (data collected in 2007-08) are discussed. The article also discusses the use of adult equivalent body mass index (BMI) cut-offs for screening for overweight and obesity in Indian children. **Results and Conclusions:** For the assessment of height, weight and BMI, WHO growth standards (for children < 5 years) and contemporary cross sectional reference percentile curves (for children from 5-18 years) are available for clinical use and for research purposes. BMI percentiles (adjusted for the Asian adult BMI equivalent cut-offs) for the assessment of physical growth of present day Indian children are also available. LMS values and Microsoft excel macro for calculating SD scores can be obtained from the author (email: vamankhadilkar@gmail.com). Contemporary growth charts can be obtained by sending a message to 08861201183 or email: gntd@novonordisk.com.

**Key words:** Children, growth, India, reference, standard

## Introduction

The assessment of growth by objective anthropometric methods of weight, length/height, and body mass index (BMI) is crucial in child care to assess the nutritional status and for the identification of growth failure. Reference data are central to growth monitoring and they help doctors, health care workers, and policymakers to diagnose under nutrition, overweight and obesity, and other growth-related and endocrine conditions.

The pattern of growth of children changes with time and hence it is recommended that references should be updated regularly.[1] India is in a phase of nutritional transition and thus it is vital to update growth references regularly.[2] The previously available growth reference curves in India were based on the data collected by Agarwal *et al.* in 1989 which were published in 1992 and 1994 and were then adopted by the Indian Academy of Pediatrics for growth monitoring in 2007.[3-5] World Health Organization (WHO) published new growth standards for children under the age of 5 years in 2006 which are being adopted in many countries including India as a global single standard of childhood growth for the under five children. It is therefore important to review the recent trends in growth monitoring and merits and demerits of the currently available growth references and standards.

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### Basics of growth charts

Growth chart consists of an x axis which is usually age in years or months and a y axis that changes according to the reference e.g., it can be height in cm or inches, weight in kg or body mass index in kg/m$^2$. The x axis is usually divided into 12 equal parts (months) for each year, but some countries such as United Kingdom use decimal ages

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where each year is divided into 10 parts. WHO, Centers for Disease Control and Prevention (CDC) and Indian charts use 12 (monthly) divisions for each year. Standard growth chart has 7 percentile lines and include 3rd, 10th, 25th, 50th, 75th, and 97th percentiles. These percentiles are standard for height and weight charts. Any individual who is below 3rd and above 97th percentile is considered out of normal range. For the BMI charts, however, there are 85th and 95th percentile lines which indicate overweight and obesity cut offs. Proportion charts use Z score lines instead of percentile lines and discrepancy of more than 2Z scores in the upper and lower segment is considered abnormal. On the growth velocity chart, 25th percentile is the cut off line for defining low height velocity. The correlation between Z scores and percentiles can be confusing and in the recent WHO Multicenter Growth Reference (MGRS) 2006 study, these correlations have been spelt out by the WHO and are given the Table 1 below for clarity of understanding.

Doctors and health care workers find it difficult to interpret various cut offs for diagnosis of underweight, overweight, stunting, wasting etc. which have also been clearly spelt out in the new WHO MGRS study and are given below [Table 2]. These make it easy for the practicing pediatrician and health care worker to follow as a guideline for management and referral.[6]

### Importance of anthropometry over tests

Anthropometry scores over all the available endocrine tests in the assessment of growth failure. Hence, it is of paramount importance that appropriate growth charts are used. Plotting a child's growth must always be the starting point in the investigations of growth failure. Longitudinal data plotted over a period of time is far more useful than a single record of height and weight. Observation of growth pattern usually over a period of minimum one year is necessary before a child is subjected to rigorous endocrine evaluation.

**Table 1: Correlation between percentiles and Z scores for World Health Organization charts**

| Z-Score | Exact percentile | Rounded percentile |
|---|---|---|
| 0 | 50 | 50 |
| -1 | 15.9 | 15 |
| -2 | 2.3 | 3 |
| -3 | 0.1 | 1 |
| 1 | 84.1 | 85 |
| 2 | 97.7 | 97 |
| 3 | 99.9 | 99 |

**Table 2: Growth parameters and their interpretation for the World Health Organization charts**

| Z Score (percentile) | Length/height for age | Weight for age | BMI for age |
|---|---|---|---|
| >3 (99) | May be abnormal | May be abnormal (Use BMI) | Obese |
| >2 (97) | Normal | Use BMI | Overweight |
| >1 (85) | Normal | Use BMI | Risk of overweight |
| 0 (50) | Normal | Use BMI | Normal |
| <-1 (15) | Normal | Normal | Normal |
| <-2 (3) | Stunted | Underweight | Wasted |
| <-3 (1) | Severely Stunted | Severely underweight | Severe wasted |

BMI: Body mass index

## Growth Standard Vs Reference

Growth charts mainly belong to two types: growth standards and growth references. Growth standards are prescriptive and define how a population of children should grow given the optimal nutrition and optimal health. Growth references on the other hand are descriptive and are prepared from a population which is thought to be growing in the best possible state of nutrition and health in a given community. These describe the growth of children at that time. They represent how children are growing rather than how they should be growing.

WHO 2006 growth charts for children under 5 years is an example of growth standards. They delineate how children of the world under the age of 5 years should grow if most of the controllable variables are kept optimal as opposed to this 1989 Agarwal *et al.*,[3] data and 2007 Indian growth charts by Khadilkar *et al.*,[7] for affluent children are an example of growth references which describe how children in India were growing at the given time.

### Strengths and shortcomings of both

Advantage of having a growth standard such as WHO 2006 charts is that children of all countries, races, ethnicity can be compared against a single standard thus assessment becomes more objective and easy to compare. The disadvantage of using charts such as these is that they are likely to over diagnose underweight and stunting in a large number of apparently normal children[8] in the developing countries such as India.

Advantage of a reference is that they are true representative of the existing growth pattern of children and allow us to study the secular trend in terms of height, weight, and obesity. The downside of reference curves is that they need to be updated at least once in a decade and in modern times as obesity is on the rise they are likely to define overweight children as normal.

## World Health Organization 2006 Growth Standards

In 2006, WHO produced growth standards for children

under the age of 5 years. The standards are derived from children who were raised in environments that minimized constraints to growth such as poor diets and infection. In addition, their mothers followed healthy practices such as breastfeeding, and not smoking during and after pregnancy. Because the standards depict physiological human growth under optimal environmental conditions, they provide an improved tool for assessing growth. These charts thus are prescriptive standards and not descriptive references.

These standards provide an opportunity to redefine and revitalize actions to promote optimal child growth, foster the adoption of "best practices", such as incorporating height and BMI to assess the dual burden of under- and over-nutrition (stunting and overweight); provide coherence between national and international infant feeding guidelines that recommend breastfeeding as the optimal source of nutrition during infancy and the charts are recommended for assessing the pattern of infant growth; and harmonize growth assessment systems within and between countries.[9]

WHO recommends using -2Z (3rd percentile) scores for diagnosis of stunting and underweight and -3Z (1st percentile) for the diagnosis of severe stunting and severe underweight.

### How India and other countries perform on these charts

Use of WHO 2006 growth charts are likely over diagnosed stunting or underweight or both in developing countries. In a recent multicentric study done on 1493 affluent preschool Indian children (selected from all zones of India) published by the author the Mean Z scores for height, weight, BMI, and weight for height (-0.75(1.1), -0.59(1.1), –0.19(1.22) and -0.26(1.18), respectively) were below the WHO 2006 standards. The overall incidence of stunting was 13.6% and underweight was 8.5% amongst affluent Indian children under the age of five years. This percentage is likely to be higher in rural areas and in under privileged urban areas although at the present time no such data is available from India.

Concerns regarding adoption of new WHO 2006 is also expressed by many authors from many parts of the world such as Indonesia, Czechoslovakia, Malawi etc. as these standards are likely to over diagnose stunting and underweight. Many authors have expressed caution regarding changing infant feeding policies based on WHO standards for the present time.

## New 2007 Affluent Indian Growth Charts [Figures 1-4]

### The need for new charts

The previously available growth reference curves in India were based on the data collected by Agarwal *et al.* in 1989 which were published in 1992 and 1994 and are almost two decades old. WHO recommends that each country should update its growth references every decade and hence new growth references were produced in 2009.

### Data collection

The Indian Academy of Pediatrics divides India into five zones, i.e., North, South, East, West, and Central. The nutritionally well off areas were identified based on per capita income of cities (from IAP zones). Data collection lasted from June 2007 to January 2008. Of the 19834 children measured, measurements for 18666 were analyzed (10496 boys and 8170 girls) where 5184 (3218 boys, 1966 girls) 3000 (1678 boys, 1322 girls), 698 (696 boys, 1002 girls) 6920 (3837 boys, 3083 girls), and 1864 (1067 boys, 797 girls) children were from the North, South, East, West, and Central zones, respectively. The differences between the zones were not significant. Standard percentiles were generated for height, weight, and BMI.

### Method used and its strength

The cleaned data were then analyzed using the LMS method, which constructs growth reference percentiles adjusted for skewness.[10] Each growth reference was summarized by 3 smooth curves plotted against age representing the median (M), the coefficient of variation (S) and the skewness (L) of the measurement distribution.[11] The models were checked for goodness of fit using the detrended Q-Q plot, Q Tests and worm plots. Least mean square (LMS) method is the universally accepted method for construction of growth charts as and it has certain advantage. The fitting procedure ensures that the values of LMS change smoothly with age so that they can be represented as smooth curves plotted against age, since these curves are smooth the resulting percentiles are also smooth, data is normalized using Box Cox transformation and any number of percentiles can be generated.

### Observations

#### *Secular trends in height*

The 50th percentile for boys' height was greater than that of the 1989 data at all ages. The 97th percentile at 18 years was 1.7 cm greater than the percentile in 1989. The 50th percentile for girls' height was greater than the percentile in 1989 at most ages, the greatest difference being 3.1 cm at 12 years. The median final height for girls was similar to 1989, but the 97th percentile was 2.4 cm greater, indicating increased variability.

#### *Alarming rise in obesity*

The 50th percentile for boys' weight was greater than the percentile in 1989 at all ages except five years, maximum

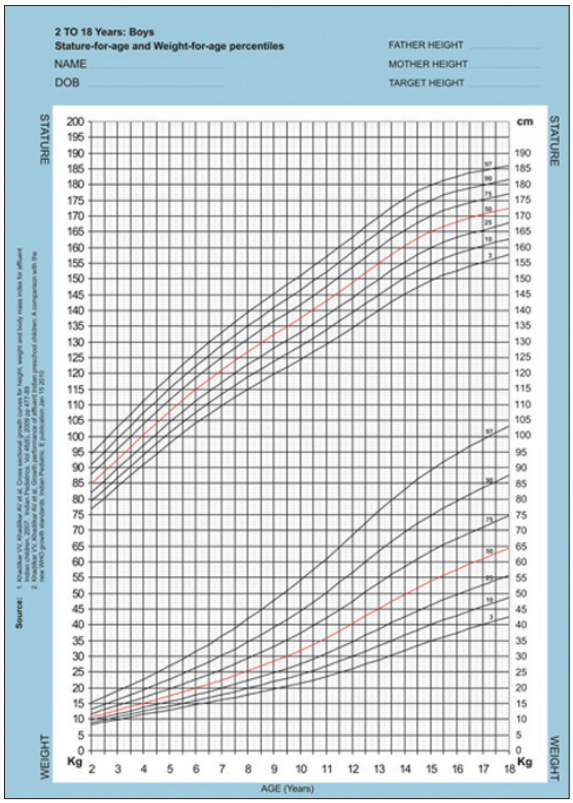


**Figure 1:** Growth chart for stature and weight for Indian boys

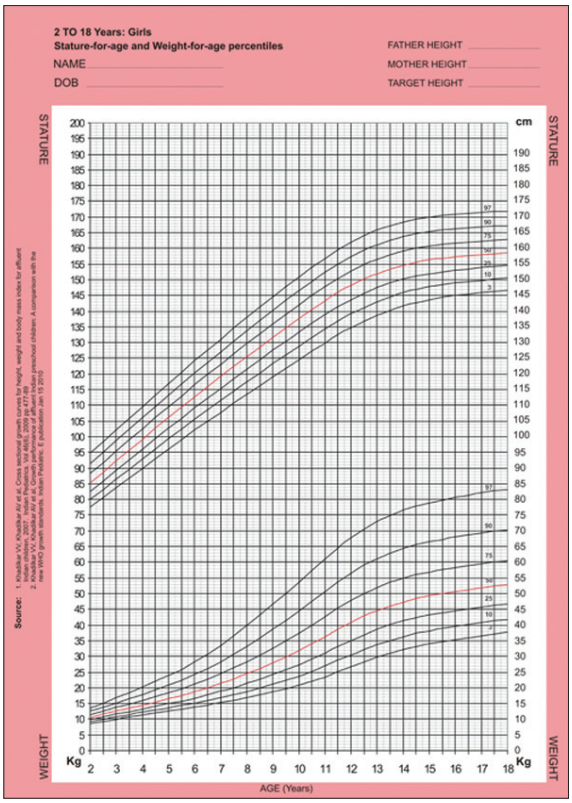


**Figure 2:** Growth chart for stature and weight for Indian girls

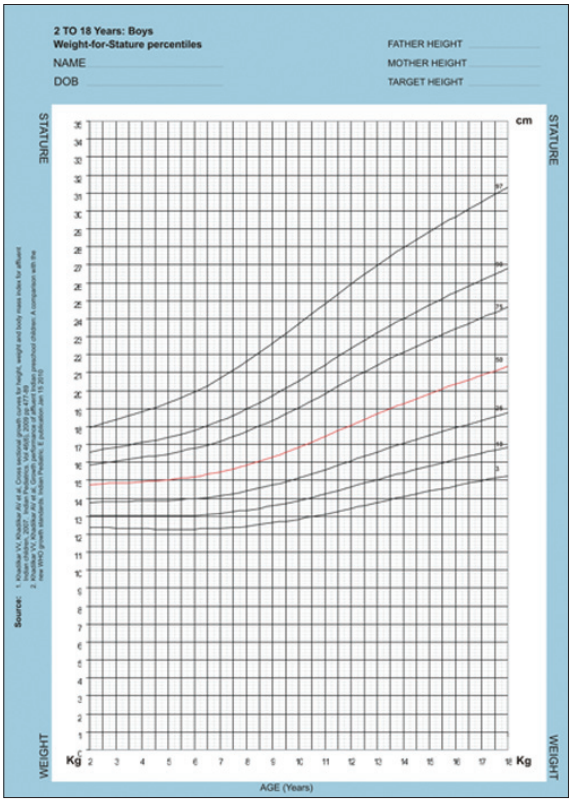


**Figure 3:** Body mass index charts for Indian boys

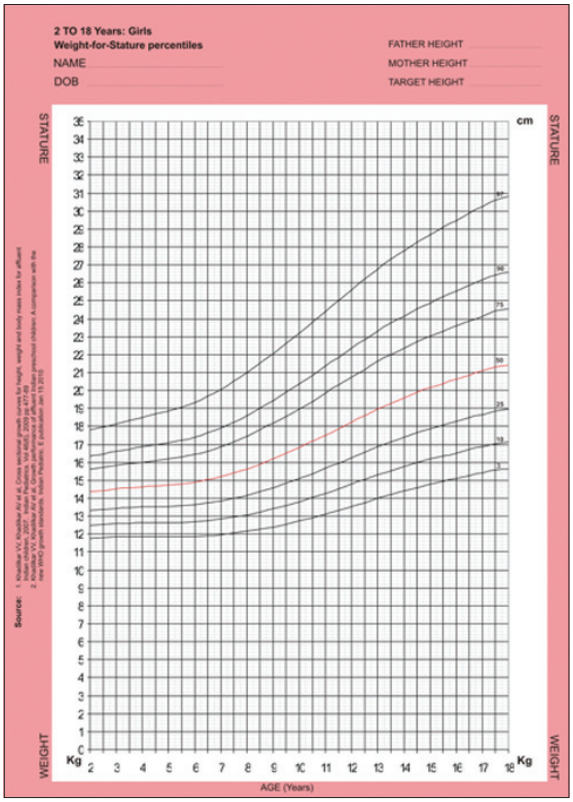


**Figure 4:** Body mass index charts for Indian girls

6.5 kg at 14 years reducing to 2.9 kg at 18 years. At 18 years, the 97th percentile was 14.7 kg higher than the percentile in 1989. The 50th percentile for girls' weight was lower than the 1989 up to the age of 6.5 years and higher afterwards, maximum 8.0 kg at 17 years. Unlike in boys, there was no reduction in difference in weight approaching adulthood. Compared with the 1989 data, average difference in the 97th percentile was similar to the 50th percentile (6.8 kg and 4.7 kg, respectively) in girls which was in stark contrast to the data on boys, where the difference was much greater (12.8 kg and 4.1 kg, respectively). In boys, the median BMI values were higher at almost all ages compared with the 1989 data. The difference in the 95th percentile in the two datasets was 2.3 at 18 years. In girls, the median BMI values were higher at almost all ages, the maximum difference being 1.1 kg/m$^2$ at 18 years.[7]

This dataset was examined for the prevalence of overweight and obesity by international standards. The overall prevalence of overweight and obesity was 18.2% by the IOTF classification and 23.9% by WHO standards. The prevalence of overweight and obesity was higher in boys than in girls. Mean BMI values were significantly higher than those reported in the 1989 data from 5 – 17 years at all ages and for both sexes. The rising trend of BMI in Indian children and adolescents observed in this multicentric study rings alarm bells in terms of associated adverse health consequences in adulthood.[12]

### *Comparison with CDC and UK Charts*

On comparison with the US (NCHS 2000) and UK (1990) data, the height percentiles for both boys and girls are similar until the age of puberty but thereafter, Indian affluent children remain shorter and do not show the pronounced pubertal spurt. This is seen in both the sexes and may be related to genetic difference in the populations. On the BMI charts, the 75th percentile for the current data was very close to the US and UK 85th percentile on BMI charts, especially after seven years in boys and nine years in girls. Boys on the 75th percentile in our study had a mean BMI of 24.2 and girls had a mean BMI of 24 at 18 years, this value is just under the adult cut-off (25) for overweight.[13] Seventy-fifth percentile values on the current BMI curves may therefore be used as a cutoff for screening for overweight boys and girls.

### *Body mass index charts*

As obesity in childhood is increasing around the world, using descriptive growth charts for weight may under-diagnose obesity in children as these charts tend to "normalize" obese children as the whole population from where the data is collected is on the higher side of the weight scale. It is therefore suggested that we use prescriptive growth standards for BMI in children. Such charts are made available by the WHO for children under the age of five years. For older children, IOTF has published BMI charts which are adjusted to adult equivalent cut offs of 25 and 30 BMI at 18 years of age. These charts are thus more appropriate for older children of the world.

WHO, however, recommends that for adult Asian Indians the BMI cut off value for overweight should be 23 and for obesity 28. It is thus important that based on the models such as IOTF, cut offs standards for BMI at 23 and 28 adult equivalent are produced to screen Indian children for overweight and obesity from five year onwards (below five years, WHO MGRS has defined the cut offs already). We, therefore, constructed BMI charts with adult 23 and 28 equivalent cutoffs for Indian boys and girls. These were validated against a total of 250 children from schools and a tertiary care pediatric clinic. The children were distributed over the whole range of BMI categories (adult equivalent BMI of <23, 23-25, 25-28, 28-30 and >30) (mean age 11.4±2.9 years). Forty three percent children in the adult equivalent BMI category of 23-25 had one or more than one risk factor for development of the metabolic syndrome (MS). Similarly, 73% children in the BMI category of adult equivalent of 28-30 had one or more than one risk factor for developing the MS and would be classified as overweight rather than obese if an adult equivalent cut-off of 30 were to be used. This validation suggests that Indian children above the adult 23 cut-off are already showing risk factors for the development of MS and hence it is appropriate to use these cut-offs for screening children who are at increased risk of later development of MS.[14]

Thus, with these three recent studies contemporary cross sectional reference percentile curves for height, weight, and BMI (adjusted for the Asian adult BMI equivalent cut-offs) for the assessment of physical growth of present day Indian children are thus made available for clinical use and for research purpose.

LMS values and Microsoft excel macro for calculating LMS values are produced for research purpose and can be obtained from the author by sending an email to vamankhadilkar@gmail.com. Similarly, 2007 growth charts can be obtained by sending a message or contacting Mr. Ganesh on 08861201183 or write to gntd@novonordisk.com.

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