# Nationwide reference data for height, weight and body mass index of Indian schoolchildren

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## ABSTRACT

***Background.*** The assessment of growth is crucial for child care and reference data are central to growth monitoring. We aimed to assess the height, weight and body mass index (BMI) of Indian schoolchildren in order to develop gender-appropriate growth charts for children 5–18 years of age.

***Methods.*** Cross-sectional evaluation of anthropometric parameters (height, weight and BMI) was done in Indian school-children (3–18 years) randomly selected from both fee-paying (upper socioeconomic strata) and non-fee paying (lower socio-economic strata) schools from 4 regions (north, south, east and west) of India. A total of 106 843 children were evaluated, of which 42 214 children (19 303 boys, 22 911 girls) were from the lower socioeconomic strata and 64 629 children (34 411 boys, 30 218 girls) were from the upper socioeconomic strata. Normative charts, using the lambda–mu–sigma (LMS) method to smoothen the curves, were drawn from children belonging to the upper socioeconomic strata, in view of the gross discrepancy between the two socioeconomic strata.

***Results.*** Height, weight and BMI percentile (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 97th) data were calculated and charts generated. The height of boys and girls was consistently higher at all ages when compared with earlier India data, but the final height was 2–4 cm lower than that reported in the WHO multicentre study of 2007. Weight centiles showed a rising trend both in boys and girls compared not only to earlier Indian data published in 1992, but also to that reported by the WHO multicentre study. The median weight at all ages in both boys and girls was approximately 4 kg more than that reported in affluent Indian children two decades earlier.

***Conclusion.*** This large nationwide study indicates secular trends in height, weight and BMI in Indian children from the upper socioeconomic strata. We suggest that the height and weight percentiles reported by us may be used as reference standards for India.

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## INTRODUCTION

Anthropometric parameters are frequently used by physicians and health workers as a valuable instrument to define nutritional status, and assess the growth and development of children.[1–3] Decisions for policy-making and planning in public health nutrition must be based on accurate anthropometric information on the population for which it is intended to be used. Since somatic growth is an indicator of a child's health and nutrition, updated population-specific reference growth charts are needed. This need has been further reinforced and recommended based on the observation that over the past few decades, children worldwide have become taller and heavier.[4,5]

India is undergoing a major transition and a secular trend is evident from publications spanning the past 4 decades. The Indian Council of Medical Research (ICMR) conducted the first study on children from the lower socioeconomic strata (LSES) more than 4 decades ago (1956–1965).[6] Subsequently, several studies have tried to formulate reference data, but in view of the small sample sizes recruited and the predominantly regional nature of these, the findings could not be considered truly representative of the whole country.[7–9] While Agarwal *et al*. published the results of a large multicentre survey of children from the upper socioeconomic strata (USES) conducted in 12 cities from all regions of India in 1992, these data are now 2 decades old.[10] Another multicentre study done recently by Khadilkar *et al*. documented a secular trend in the height and weight of schoolchildren but was based on a smaller sample size.[11]

We present national cross-sectional growth charts for height, weight and BMI, drawn on the basis of a large sample of Indian schoolchildren aged 5–18 years belonging to the USES, covering 4 major regions of India. To generate age- and gender-appropriate centile curves for future reference, we used data only from USES schoolchildren to nullify any environmental growth constraints that are still widely prevalent in India.

## METHODS

Schoolchildren (both boys and girls) in the age group of 3–18 years, studying in government and private schools located in 19 cities from 4 different geographical zones (north, south, east and west) of

India were studied from January 2006 to December 2009. (Details of children studied from each city are provided in Supplementary Table I, available at *www.nmji.in*) Schools from each zone were selected on the basis of permission granted by the school authorities. The classification of schools was done according to the fee pattern. Children attending government (non-fee paying) schools were considered to represent the LSES, while those attending private (fee-paying) schools were considered representative of the USES, as reported in our earlier studies.[12–15] Children were categorized according to yearly intervals based on completed years of age. The study protocol was approved by the institutional ethics committee of the Institute of Nuclear Medicine and Allied Sciences (INMAS). Prior consent for the study was taken from the school administrations. At the time of initiating the study, the parents of each participant were informed about the study protocol and written consent of parents was obtained prior to their child's participation.

The entire cohort underwent assessment of height and weight, along with other evaluation as part of a comprehensive health survey of these children. The staff were trained by the two principal investigators (RKM, NT) in the correct procedure and how to take accurate anthropometric measurements at the start of the study. The same staff travelled to all the cities where the study was conducted, thereby ensuring uniformity in measurements. Height was measured to the nearest 0.1 cm using a portable wall-mounted stadiometer (200 cm/78 inches) Model WS045 (Narang Medical Limited, Delhi) with the subject standing straight with the head held in the Frankfurt horizontal plane. The subject's weight, without shoes and while wearing light clothes, was measured to the nearest 0.1 kg, using an electronic scale (EQUINOX Digital weighing machine, Model EB6171). Height and weight measurements were taken twice and the mean of the two measurements was used to calculate the BMI, which was defined as the ratio of body weight (in kg) to body height (in metres) squared (kg/m$^2$). Every morning, the scale and stadiometer were calibrated with standard weight and height, respectively. The intra-observer and inter-observer coefficients of variation between the three members of the research team (KB, MP, S) who travelled to all regions and were exclusively involved in taking anthropometric measurements were <1%.

Data were recorded on a pre-designed proforma. Height, weight and BMI percentile charts were generated by using the lambda–mu–sigma (LMS) method, which is currently the recommended method for generating centiles.[16] The LMS regressions were done using the LMS Pro software (The Institute of Child Health, London). The data were first examined for outliers. The LMS method was used to obtain smoothed centile curves for each of the anthropometric variables. The need for centile curves arises when the measurement is strongly dependent on some covariate, often age, so that the reference range changes with the covariate. The LMS method uses Box–Cox power transformation, which deals with the skewness present in the distribution of the anthropometric measurement and provides a way to normalize the measurement. The final centile curves are the result of smoothing three age-specific curves called L (lambda), M (mu) and S (sigma). The M and S curves correspond to the median and coefficient of variation of the measurement at each age, whereas the L curve allows for substantial age-dependent skewness in the distribution of the measurement. The points on each centile curve are defined by the following formula:

$$M (1+LSz)1/L,$$

where L, M and S are the values of the fitted curves at each age, and z denotes the z score, i.e. the standard score with mean 0 and a standard deviation of 1, for the required centile, for example, z=1.645 for the 95th centile. The main assumption underlying the LMS method is that after Box–Cox power transformation, the data at each age are normally distributed.

Analysis was done using the intercooled STATA 8.0 (College station, TX77845, USA) statistical software.

## RESULTS

We evaluated a total of 106 843 children, aged 3–18 years, of which 53 714 (50.23%) were boys (LSES 19 303; USES, 34 411) and 53 129 (49.72%) were girls (LSES 22 911; USES 30 218). The number of girls and boys in each age group in the total population and in those hailing from the USES are shown in Supplementary Tables II and III (available at *www.nmji.in*).

A striking difference was observed in the heights and weights of children belonging to the USES and LSES across all age groups. Data from 3 age groups, serving as examples to depict this difference, are provided in Table I. Children from the USES were taller and heavier, not only when compared with those belonging to the LSES, but also when compared with the combined cohort.

In view of these differences, we selected USES children to define normative curves as they are less likely than LSES children to have been exposed to environmental constraints of growth. The percentile curves for height, weight and BMI generated from all children (Supplementary Tables IV–VII) and those belonging to the USES category are shown in Tables II–VII and Figs 1–6.

Comparisons of the present height and weight curves with earlier data from India[10,11] and multicountry data from WHO[4] are shown in Figs 7–10.

## DISCUSSION

It is suggested that environmental factors are major determinants of disparities in physical growth.[3] In view of the changing pattern

TABLE I. Comparison of height, weight and BMI centiles (3rd, 50th and 97th) of lower socioeconomic strata (LSES) *v.* upper socioeconomic strata (USES) schoolgirls and schoolboys at ages 3, 10 and 18 years

| Age (years) | LSES boys | | | USES boys | | | LSES girls | | | USES girls | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd | 50th | 97th | 3rd | 50th | 97th | 3rd | 50th | 97th | 3rd | 50th | 97th |
| | | | | | | Height (cm) | | | | | | |
| 3 | 88.4 | 97.2 | 109.0 | 91.2 | 101.2 | 111.6 | 87.1 | 96.0 | 112.3 | 90.4 | 99.5 | 111.0 |
| 10 | 117.8 | 132.9 | 148.6 | 125.4 | 138.6 | 152.2 | 118.8 | 133.3 | 146.9 | 126.3 | 139.5 | 151.9 |
| 18 | 155.2 | 169.1 | 181.5 | 160.4 | 174.4 | 185.5 | 146.7 | 154.6 | 164.6 | 149.1 | 158.5 | 168.0 |
| | | | | | | Weight (kg) | | | | | | |
| 3 | 11.0 | 13.5 | 17.9 | 10.8 | 14.0 | 21.0 | 10.4 | 13.0 | 19.0 | 10.3 | 13.8 | 20.8 |
| 10 | 19.1 | 26.3 | 39.8 | 22.6 | 33.0 | 53.3 | 19.1 | 26.5 | 39.4 | 22.9 | 33.8 | 52.7 |
| 18 | 40.7 | 54.7 | 78.4 | 45.7 | 66.2 | 98.5 | 37.1 | 46.5 | 62.8 | 40.8 | 55.6 | 80.1 |

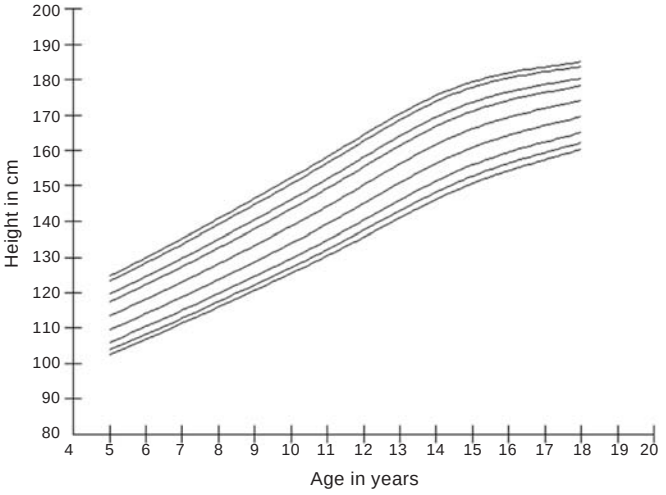



FIG 1. Height percentiles of upper socioeconomic strata boys aged 5–18 years

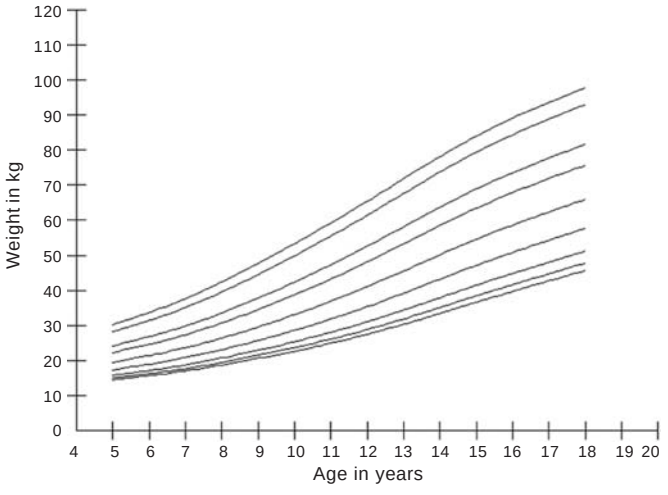



FIG 2. Weight percentiles of upper socioeconomic strata boys aged 5–18 years

TABLE II. Height (cm) centiles of 3–18-year-old Indian schoolboys belonging to the upper socioeconomic strata

| Age (years) | Height percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 91.19 | 92.42 | 94.34 | 97.57 | 101.20 | 104.88 | 106.87 | 110.25 | 111.57 |
| 4 | 96.38 | 97.67 | 99.67 | 103.04 | 106.84 | 110.70 | 112.79 | 116.33 | 117.72 |
| 5 | 101.51 | 102.85 | 104.93 | 108.44 | 112.40 | 116.42 | 118.60 | 122.32 | 123.77 |
| 6 | 106.44 | 107.83 | 109.98 | 113.63 | 117.74 | 121.92 | 124.19 | 128.06 | 129.57 |
| 7 | 111.22 | 112.66 | 114.89 | 118.66 | 122.93 | 127.26 | 129.62 | 133.64 | 135.21 |
| 8 | 115.95 | 117.45 | 119.76 | 123.68 | 128.10 | 132.60 | 135.04 | 139.20 | 140.83 |
| 9 | 120.66 | 122.22 | 124.63 | 128.70 | 133.30 | 137.96 | 140.49 | 144.79 | 146.48 |
| 10 | 125.44 | 127.07 | 129.60 | 133.86 | 138.64 | 143.47 | 146.08 | 150.50 | 152.23 |
| 11 | 130.40 | 132.13 | 134.80 | 139.28 | 144.25 | 149.24 | 151.92 | 156.42 | 158.17 |
| 12 | 135.61 | 137.46 | 140.30 | 144.99 | 150.15 | 155.26 | 157.98 | 162.52 | 164.27 |
| 13 | 140.94 | 142.90 | 145.88 | 150.77 | 156.07 | 161.23 | 163.95 | 168.45 | 170.17 |
| 14 | 146.02 | 148.06 | 151.15 | 156.14 | 161.47 | 166.59 | 169.26 | 173.64 | 175.31 |
| 15 | 150.47 | 152.56 | 155.67 | 160.66 | 165.91 | 170.88 | 173.46 | 177.64 | 179.22 |
| 16 | 154.17 | 156.24 | 159.33 | 164.21 | 169.29 | 174.04 | 176.48 | 180.42 | 181.90 |
| 17 | 157.34 | 159.38 | 162.39 | 167.11 | 171.96 | 176.46 | 178.75 | 182.44 | 183.81 |
| 18 | 160.39 | 162.37 | 165.27 | 169.79 | 174.39 | 178.62 | 180.77 | 184.20 | 185.48 |

TABLE III. Weight (kg) centiles of 3–18-year-old Indian schoolboys belonging to the upper socioeconomic strata

| Age (years) | Weight percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 10.77 | 11.09 | 11.61 | 12.63 | 14.03 | 15.85 | 17.08 | 19.73 | 21.04 |
| 4 | 12.53 | 12.92 | 13.57 | 14.83 | 16.57 | 18.84 | 20.36 | 23.66 | 25.28 |
| 5 | 14.16 | 14.62 | 15.40 | 16.91 | 19.01 | 21.74 | 23.58 | 27.53 | 29.47 |
| 6 | 15.61 | 16.15 | 17.06 | 18.84 | 21.30 | 24.50 | 26.65 | 31.25 | 33.50 |
| 7 | 17.07 | 17.70 | 18.76 | 20.83 | 23.69 | 27.40 | 29.88 | 35.16 | 37.71 |
| 8 | 18.72 | 19.46 | 20.69 | 23.10 | 26.43 | 30.72 | 33.57 | 39.58 | 42.46 |
| 9 | 20.57 | 21.43 | 22.87 | 25.68 | 29.54 | 34.48 | 37.73 | 44.49 | 47.68 |
| 10 | 22.63 | 23.63 | 25.32 | 28.58 | 33.03 | 38.66 | 42.31 | 49.81 | 53.28 |
| 11 | 24.91 | 26.07 | 28.02 | 31.78 | 36.86 | 43.20 | 47.27 | 55.45 | 59.18 |
| 12 | 27.45 | 28.78 | 31.02 | 35.29 | 41.03 | 48.08 | 52.54 | 61.38 | 65.35 |
| 13 | 30.27 | 31.78 | 34.29 | 39.09 | 45.45 | 53.19 | 58.03 | 67.50 | 71.70 |
| 14 | 33.32 | 34.99 | 37.77 | 43.03 | 49.98 | 58.33 | 63.52 | 73.57 | 77.98 |
| 15 | 36.46 | 38.27 | 41.27 | 46.94 | 54.37 | 63.25 | 68.72 | 79.25 | 83.85 |
| 16 | 39.58 | 41.51 | 44.70 | 50.69 | 58.51 | 67.80 | 73.50 | 84.41 | 89.16 |
| 17 | 42.64 | 44.67 | 48.01 | 54.29 | 62.42 | 72.04 | 77.92 | 89.12 | 93.97 |
| 18 | 45.70 | 47.82 | 51.31 | 57.83 | 66.25 | 76.14 | 82.17 | 93.60 | 98.53 |

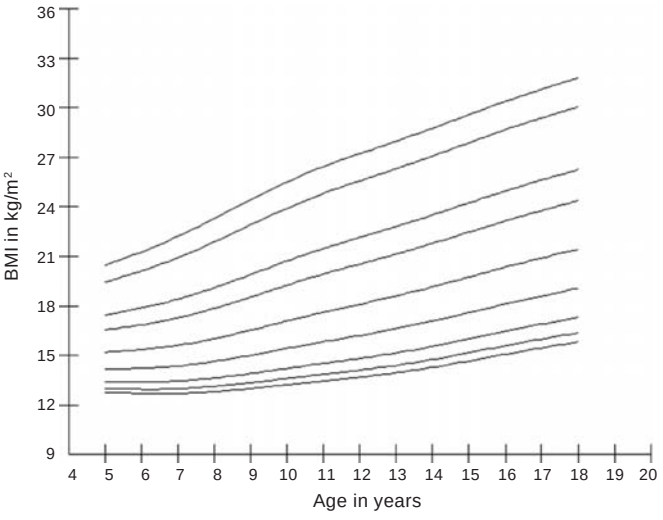



FIG 3. Body mass index (BMI) percentiles of upper socioeconomic strata boys aged 5–18 years

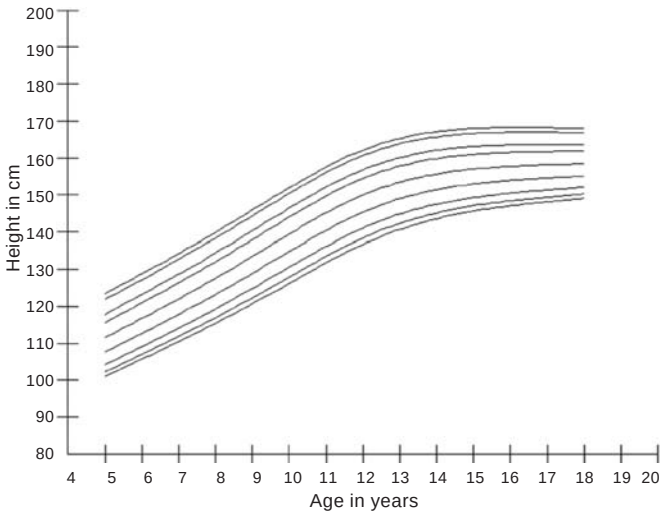



FIG 4. Height percentiles of upper socioeconomic strata girls aged 5–18 years

TABLE IV. Body mass index (BMI; kg/m²) centiles of 3–18-year-old Indian schoolboys belonging to the upper socioeconomic strata

| Age (years) | BMI percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 12.66 | 12.86 | 13.19 | 13.82 | 14.66 | 15.72 | 16.41 | 17.87 | 18.58 |
| 4 | 12.66 | 12.90 | 13.27 | 13.97 | 14.91 | 16.12 | 16.92 | 18.63 | 19.48 |
| 5 | 12.69 | 12.93 | 13.33 | 14.10 | 15.15 | 16.50 | 17.41 | 19.38 | 20.37 |
| 6 | 12.68 | 12.94 | 13.37 | 14.21 | 15.37 | 16.87 | 17.89 | 20.12 | 21.26 |
| 7 | 12.70 | 12.99 | 13.46 | 14.38 | 15.65 | 17.31 | 18.44 | 20.94 | 22.21 |
| 8 | 12.82 | 13.13 | 13.65 | 14.65 | 16.05 | 17.88 | 19.13 | 21.89 | 23.29 |
| 9 | 13.00 | 13.34 | 13.91 | 15.01 | 16.54 | 18.54 | 19.90 | 22.90 | 24.40 |
| 10 | 13.23 | 13.60 | 14.22 | 15.42 | 17.08 | 19.24 | 20.71 | 23.89 | 25.47 |
| 11 | 13.46 | 13.86 | 14.53 | 15.82 | 17.61 | 19.91 | 21.46 | 24.78 | 26.41 |
| 12 | 13.69 | 14.12 | 14.83 | 16.21 | 18.10 | 20.53 | 22.15 | 25.57 | 27.22 |
| 13 | 13.96 | 14.41 | 15.17 | 16.62 | 18.61 | 21.14 | 22.82 | 26.32 | 27.98 |
| 14 | 14.29 | 14.76 | 15.56 | 17.09 | 19.16 | 21.80 | 23.52 | 27.10 | 28.78 |
| 15 | 14.66 | 15.16 | 15.99 | 17.59 | 19.75 | 22.47 | 24.25 | 27.90 | 29.60 |
| 16 | 15.06 | 15.58 | 16.44 | 18.10 | 20.34 | 23.15 | 24.97 | 28.69 | 30.42 |
| 17 | 15.44 | 15.98 | 16.87 | 18.59 | 20.91 | 23.79 | 25.65 | 29.43 | 31.17 |
| 18 | 15.80 | 16.36 | 17.29 | 19.07 | 21.46 | 24.42 | 26.31 | 30.14 | 31.89 |

TABLE V. Height (cm) centiles of 3–18-year-old Indian schoolgirls belonging to the upper socioeconomic strata

| Age (years) | Height percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 90.42 | 91.45 | 93.09 | 96.00 | 99.49 | 103.28 | 105.46 | 109.38 | 110.99 |
| 4 | 95.52 | 96.64 | 98.42 | 101.52 | 105.20 | 109.13 | 111.36 | 115.31 | 116.92 |
| 5 | 100.57 | 101.79 | 103.69 | 107.00 | 110.86 | 114.93 | 117.21 | 121.18 | 122.78 |
| 6 | 105.53 | 106.84 | 108.88 | 112.39 | 116.43 | 120.63 | 122.94 | 126.93 | 128.52 |
| 7 | 110.46 | 111.87 | 114.05 | 117.77 | 121.98 | 126.29 | 128.63 | 132.64 | 134.22 |
| 8 | 115.50 | 117.01 | 119.35 | 123.27 | 127.65 | 132.06 | 134.43 | 138.45 | 140.01 |
| 9 | 120.77 | 122.39 | 124.86 | 128.97 | 133.51 | 138.00 | 140.40 | 144.41 | 145.96 |
| 10 | 126.25 | 127.95 | 130.54 | 134.81 | 139.45 | 144.00 | 146.41 | 150.40 | 151.93 |
| 11 | 131.68 | 133.43 | 136.08 | 140.41 | 145.08 | 149.63 | 152.03 | 155.97 | 157.48 |
| 12 | 136.60 | 138.33 | 140.95 | 145.23 | 149.84 | 154.32 | 156.67 | 160.55 | 162.03 |
| 13 | 140.54 | 142.20 | 144.72 | 148.85 | 153.30 | 157.64 | 159.92 | 163.69 | 165.13 |
| 14 | 143.46 | 145.02 | 147.40 | 151.31 | 155.57 | 159.73 | 161.92 | 165.56 | 166.96 |
| 15 | 145.53 | 146.98 | 149.21 | 152.89 | 156.92 | 160.89 | 163.00 | 166.50 | 167.85 |
| 16 | 146.98 | 148.34 | 150.42 | 153.88 | 157.68 | 161.46 | 163.47 | 166.84 | 168.14 |
| 17 | 148.11 | 149.37 | 151.32 | 154.56 | 158.15 | 161.74 | 163.66 | 166.88 | 168.12 |
| 18 | 149.12 | 150.30 | 152.11 | 155.15 | 158.53 | 161.92 | 163.74 | 166.80 | 168.00 |

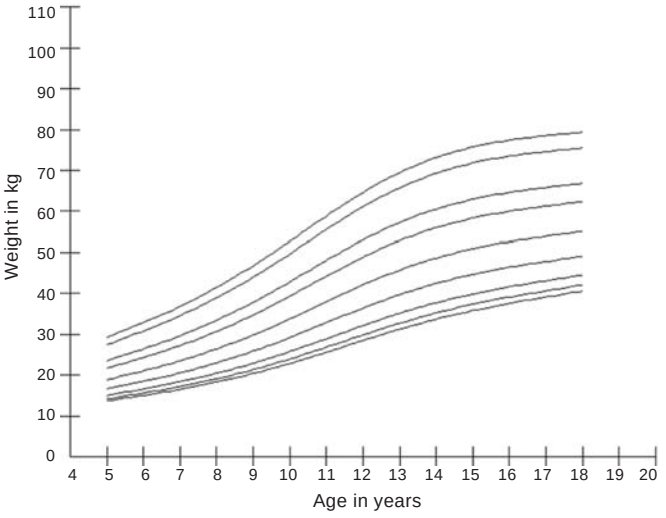



FIG 5. Weight percentiles of upper socioeconomic strata girls aged 5–18 years

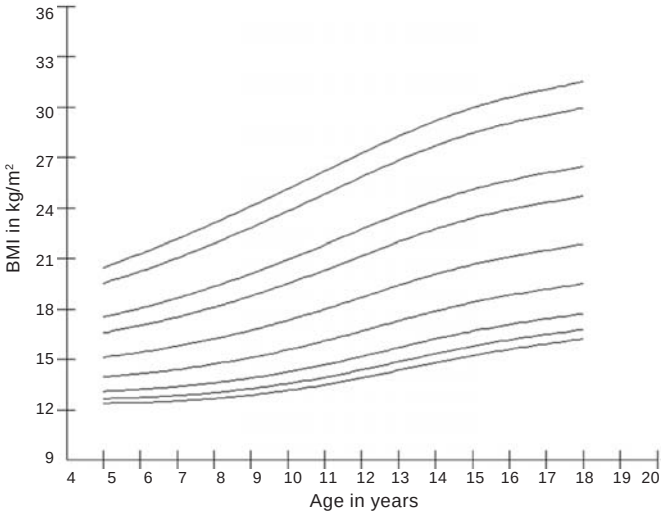



FIG 6. Body mass index (BMI) percentiles of upper socioeconomic strata girls aged 5–18 years

TABLE VI. Weight (kg) centiles of 3–18-year-old Indian schoolgirls belonging to the upper socioeconomic strata

| Age (years) | Weight percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 10.31 | 10.64 | 11.20 | 12.29 | 13.77 | 15.67 | 16.93 | 19.58 | 20.84 |
| 4 | 11.96 | 12.37 | 13.06 | 14.39 | 16.22 | 18.54 | 20.07 | 23.27 | 24.79 |
| 5 | 13.51 | 14.01 | 14.83 | 16.43 | 18.61 | 21.37 | 23.18 | 26.93 | 28.70 |
| 6 | 14.99 | 15.57 | 16.55 | 18.42 | 20.97 | 24.20 | 26.29 | 30.59 | 32.60 |
| 7 | 16.56 | 17.24 | 18.38 | 20.57 | 23.54 | 27.26 | 29.66 | 34.54 | 36.79 |
| 8 | 18.34 | 19.14 | 20.47 | 23.03 | 26.48 | 30.76 | 33.50 | 39.00 | 41.51 |
| 9 | 20.43 | 21.36 | 22.92 | 25.90 | 29.89 | 34.79 | 37.90 | 44.07 | 46.84 |
| 10 | 22.86 | 23.95 | 25.75 | 29.19 | 33.77 | 39.34 | 42.83 | 49.69 | 52.74 |
| 11 | 25.57 | 26.80 | 28.85 | 32.75 | 37.89 | 44.10 | 47.97 | 55.49 | 58.80 |
| 12 | 28.39 | 29.75 | 32.02 | 36.30 | 41.92 | 48.67 | 52.85 | 60.94 | 64.48 |
| 13 | 31.10 | 32.55 | 34.97 | 39.52 | 45.48 | 52.61 | 57.02 | 65.52 | 69.24 |
| 14 | 33.56 | 35.07 | 37.56 | 42.27 | 48.43 | 55.79 | 60.33 | 69.09 | 72.93 |
| 15 | 35.70 | 37.23 | 39.77 | 44.54 | 50.78 | 58.23 | 62.83 | 71.72 | 75.62 |
| 16 | 37.55 | 39.08 | 41.62 | 46.39 | 52.63 | 60.08 | 64.68 | 73.59 | 77.50 |
| 17 | 39.21 | 40.73 | 43.25 | 47.99 | 54.18 | 61.57 | 66.14 | 74.99 | 78.88 |
| 18 | 40.81 | 42.33 | 44.83 | 49.52 | 55.64 | 62.94 | 67.46 | 76.21 | 80.06 |

TABLE VII. Body mass index (BMI; kg/m$^2$) centiles of 3–18-year-old Indian schoolgirls belonging to the upper socioeconomic strata

| Age (years) | BMI percentiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 25 | 50 | 75 | 90 | 95 | 97 |
| 3 | 12.14 | 12.37 | 12.76 | 13.48 | 14.44 | 15.63 | 16.39 | 17.94 | 18.66 |
| 4 | 12.26 | 12.51 | 12.94 | 13.73 | 14.79 | 16.11 | 16.96 | 18.71 | 19.53 |
| 5 | 12.35 | 12.62 | 13.08 | 13.95 | 15.12 | 16.57 | 17.51 | 19.46 | 20.37 |
| 6 | 12.41 | 12.71 | 13.21 | 14.15 | 15.43 | 17.02 | 18.05 | 20.19 | 21.20 |
| 7 | 12.51 | 12.83 | 13.37 | 14.41 | 15.79 | 17.53 | 18.66 | 21.00 | 22.10 |
| 8 | 12.66 | 13.02 | 13.60 | 14.72 | 16.23 | 18.12 | 19.35 | 21.88 | 23.07 |
| 9 | 12.87 | 13.25 | 13.89 | 15.10 | 16.74 | 18.78 | 20.10 | 22.82 | 24.08 |
| 10 | 13.14 | 13.55 | 14.24 | 15.56 | 17.33 | 19.52 | 20.94 | 23.81 | 25.14 |
| 11 | 13.48 | 13.93 | 14.67 | 16.09 | 17.98 | 20.32 | 21.82 | 24.83 | 26.22 |
| 12 | 13.90 | 14.38 | 15.17 | 16.68 | 18.69 | 21.16 | 22.73 | 25.86 | 27.29 |
| 13 | 14.35 | 14.86 | 15.70 | 17.29 | 19.40 | 21.97 | 23.60 | 26.83 | 28.29 |
| 14 | 14.81 | 15.34 | 16.21 | 17.87 | 20.06 | 22.72 | 24.40 | 27.70 | 29.18 |
| 15 | 15.23 | 15.78 | 16.68 | 18.39 | 20.64 | 23.37 | 25.07 | 28.43 | 29.93 |
| 16 | 15.60 | 16.15 | 17.08 | 18.82 | 21.11 | 23.88 | 25.62 | 29.01 | 30.53 |
| 17 | 15.91 | 16.47 | 17.41 | 19.18 | 21.50 | 24.30 | 26.05 | 29.47 | 30.99 |
| 18 | 16.20 | 16.77 | 17.73 | 19.52 | 21.86 | 24.68 | 26.44 | 29.88 | 31.41 |

of growth in a population over time, it is recommended that growth references be updated regularly.[1] Several studies in the past few decades have shown that children worldwide have become taller and heavier.[4,5] Growth charts for children from Hong Kong, first published in the 1960s, were updated in 1985, and then in 1993.[17] Similarly, nationwide growth surveys have been done every 10 years in Mainland China since 1975.[18] The 1977 National Center for Health Statistics (NCHS) growth curves for US children were revised in 2000,[3] while the UK curves, first published in 1966[19] were revised in 1990.[20] All these updated reports indicate a clear secular trend, with increase in height and weight over time.

In India, a secular trend in anthropometric parameters is evident from scattered regional reports spanning the past 3–4 decades.[6–11] The first Indian attempt at evaluating the growth of normal Indian children was made by the ICMR more than 4 decades ago (1956–1965) and involved subjects predominantly drawn from the LSES.[6] Subsequently, several studies tried to reformulate reference data, but due to small sample sizes and regional recruitment, these cannot be considered truly representative of the country.[7–9] In 1992, Agarwal *et al*.[10] published the results of a large multicentre survey of growth and development of Indian children from the USES. Although it was conducted simultaneously in 12 cities from different parts of India, it is about 2 decades old and would not be applicable at present in view of the known secular trends in height and weight of children. WHO has encouraged all countries and regions throughout the world to adopt the new WHO growth standards (Multicentre Growth Reference Study, MGRS) for children below 5 years of age published in 2006, in which multicountry (including India) and community-based data were collected.[4]

Thus, there was a need to generate currently valid reference curves that are truly representative of Indian children. This study was done on 106 843 children 3–18 years of age, of whom 64 629 children were from the USES group. This USES group of children was used for generating reference values, as a significant difference was noted between the heights and weights of children belonging to the LSES and USES. We selected USES children to generate reference curves because, in our opinion, they were less likely to have been exposed to environmental constraints to growth. Even though there is evidence that the nutritional status of Indian children has improved dramatically over the years, a striking socioeconomic divide still exists.[21] This decision is also supported by earlier data wherein affluent Indian children aged 12–23 months had anthropometric indicators close to the NCHS/WHO reference population.[8]

In view of the recent secular trend reported by Khadilkar *et al*., we compared height percentiles of children from the USES in our study with those from Agarwal *et al*.[10] and Khadilkar *et al*.[11] (Figs 7 and 9). The 50th percentile of height for both boys and girls was significantly higher in our study compared not only with that reported nearly 2 decades ago by Agarwal *et al*.[10] but also with the more recent data from Khadilkar *et al*.[11] In case of the latter comparison, the difference was manifest throughout all age categories in boys, except for early adolescence (ages 14–15 years). In case of girls, the median height was consistently higher than that reported by Agarwal *et al*.[10] across all age groups. Similarly, in comparison with the data reported by Khadilkar *et al*., the median height of girls in our study was higher till the age of 12 years, after which the difference was marginal. The earlier flattening of the growth curve of girls compared with that in the study by Khadilkar *et al*. could be due to their higher weights leading to earlier puberty/pubertal spurt and consequently earlier epiphyseal closure. The 3rd percentile of heights in our study was


| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agarwal *et al*.[10] | 106.3 | 114.2 | 119.7 | 123.6 | 128.2 | 133.6 | 139.6 | 145.8 | 152.0 | 157.6 | 162.5 | 166.3 | 168.7 | 169.8 |
| WHO[4] | 110.3 | 116.0 | 121.7 | 127.3 | 132.6 | 137.8 | 143.1 | 149.1 | 156.0 | 163.2 | 169.0 | 172.9 | 175.2 | 176.1 |
| Khadilkar *et al*.[11] | 108.1 | 114.9 | 120.9 | 126.9 | 132.4 | 137.2 | 142.4 | 148.3 | 154.8 | 161.4 | 166.1 | 168.5 | 169.7 | 170.4 |
| Our study | 112.4 | 117.7 | 122.9 | 128.1 | 133.3 | 138.6 | 144.2 | 150.1 | 156.0 | 161.4 | 165.9 | 169.2 | 171.9 | 174.3 |

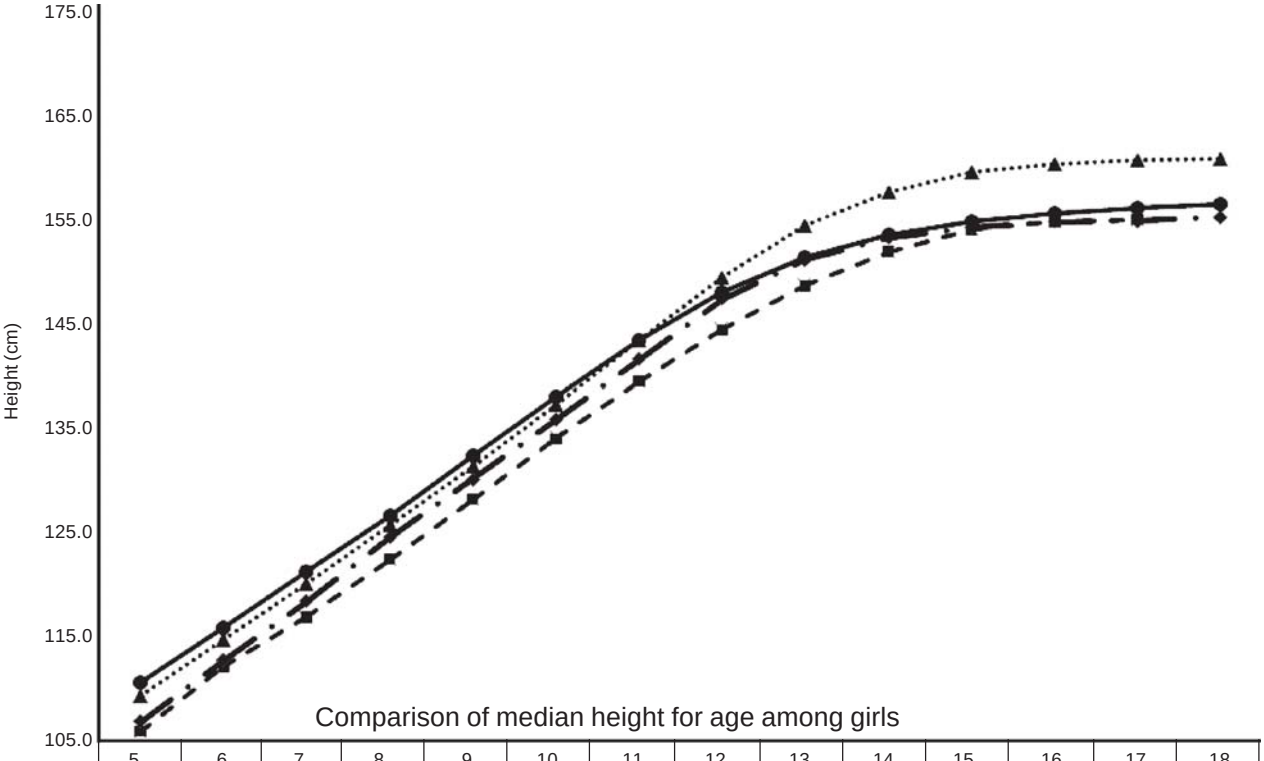
Age (years)

FIG 7. Comparison of median height percentiles of boys from our study with WHO (2006) and other Indian studies


| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agarwal *et al.*[10] | 17.1 | 19.0 | 21.0 | 22.6 | 24.4 | 27.0 | 30.6 | 34.8 | 39.4 | 44.1 | 48.5 | 52.4 | 55.5 | 58.6 |
| WHO[4] | 18.5 | 20.5 | 22.5 | 25.4 | 28.1 | 31.2 | – | – | – | – | – | – | – | – |
| Khadilkar *et al.*[11] | 17.1 | 19.8 | 22.5 | 25.4 | 28.6 | 31.7 | 35.6 | 40.5 | 45.6 | 50.6 | 54.7 | 57.7 | 59.8 | 61.5 |
| Our study | 19.0 | 21.3 | 23.7 | 26.4 | 29.5 | 33.0 | 36.9 | 41.0 | 45.4 | 49.9 | 54.3 | 58.5 | 62.4 | 66.2 |

Age (years)

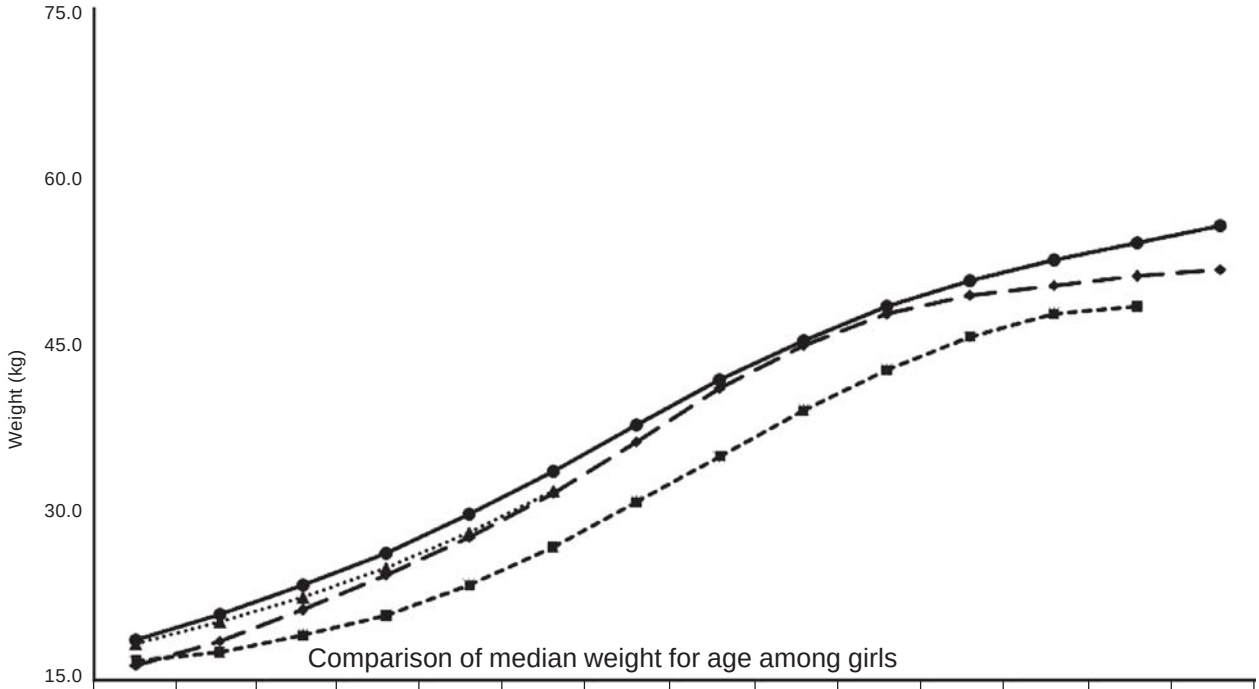
FIG 8. Comparison of median weight percentiles of boys from our study with WHO (2006) and other Indian studies




| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agarwal *et al.*[10] | 106.0 | 112.5 | 117.4 | 123.2 | 129.2 | 135.2 | 140.9 | 146.0 | 150.4 | 153.8 | 156.0 | 156.8 | 157.0 | – |
| WHO[4] | 109.6 | 115.1 | 120.8 | 126.6 | 132.5 | 138.6 | 145.0 | 151.2 | 156.4 | 159.8 | 161.7 | 162.5 | 162.9 | 163.1 |
| Khadilkar *et al.*[11] | 107.0 | 113.1 | 119.0 | 125.4 | 131.2 | 137.1 | 143.1 | 149.1 | 153.0 | 155.2 | 156.3 | 156.8 | 156.9 | 157.3 |
| Our study | 110.9 | 116.4 | 121.9 | 127.6 | 133.5 | 139.4 | 145.0 | 149.8 | 153.3 | 155.5 | 156.9 | 157.6 | 158.1 | 158.5 |

Age (years)

FIG 9. Comparison of median height percentiles of girls from our study with WHO (2006) and other Indian studies




| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agarwal *et al.*[10] | 16.8 | 17.5 | 19.0 | 20.8 | 23.5 | 26.9 | 30.9 | 35.0 | 39.1 | 42.7 | 45.7 | 47.7 | 48.4 | – |
| WHO[4] | 18.3 | 20.2 | 22.4 | 25.0 | 28.2 | 31.9 | – | – | – | – | – | – | – | – |
| Khadilkar *et al.*[11] | 16.3 | 18.5 | 21.3 | 24.4 | 27.8 | 31.7 | 36.3 | 41.1 | 44.9 | 47.7 | 49.4 | 50.3 | 51.1 | 51.7 |
| Our study | 18.6 | 20.9 | 23.5 | 26.4 | 29.8 | 33.7 | 37.8 | 41.9 | 45.4 | 48.4 | 50.7 | 52.6 | 54.1 | 55.6 |

Age (years)

FIG 10. Comparison of median weight percentiles of girls from our study with WHO (2006) and other Indian studies

also 2–3 cm more than that reported by both Agarwal *et al.*[10] and Khadilkar *et al.*,[11] especially in the younger age groups. We also compared data from our present study with our earlier data on affluent Delhi schoolchildren and found no major difference between the two.[12]

The median height of boys in our study was similar or more than that reported in the multicountry WHO study (2006)[4] till the age of 12 years. In the older age groups, the median height in the WHO study was between 2 cm and 4 cm more than that reported by us. Similarly, even in girls, the median height in our study was more than that in the WHO study till the age of 10 years, following which the median heights reported in the multicountry study were more by up to 4–5 cm. The better height performance of younger boys and girls could probably be explained by improved nutrition consequent to India's economic growth over the past decade.

A similar trend was also observed for weight percentiles in all age groups and both sexes, when we compared our data with that from earlier Indian studies (Figs 8 and 10) involving affluent schoolchildren.[10,11] In comparison with data from Agarwal *et al.*,[10] the median weights in our study, in both sexes and across all age groups, were significantly more. This difference became marked (>4 kg) after the age of 7–8 years. This secular trend was also observed when comparing data from Khadilkar *et al.*,[11] though the difference in weight was less marked. The median weights in our study are also more than those reported by WHO, though their data are limited to 10 years of age. The median BMI of girls in our study was consistently though marginally more than that reported by Khadilkar *et al.*[11] While a similar trend was also seen when comparing the median BMI of boys between the two studies, this difference was not observed between the ages of 12 and 15 years. Even the 3rd centiles of BMI across all ages and both sexes were higher than that reported by Khadilkar *et al.*[11] This comparison of weight and BMI between the present and earlier Indian studies[8–11,22] clearly indicates secular trends in childhood obesity, which are more prominent in girls than boys.

The above data are in consonance with reports of increasing prevalence of overweight and obesity in children and adolescents from across the world, including studies from India.[8–11,22–26] The International Obesity Task Force (IOTF) has recommended cut-offs of 25 kg/m$^2$ and 30 kg/m$^2$ for overweight and obesity in adults, while there is a suggestion that lower cut-offs of 23 kg/m$^2$ and 27 kg/m$^2$ should be used to define these conditions in South Asians.[26] The National Task Force for Childhood Prevention of Adult Diseases of the Indian Academy of Pediatrics has recommended that Indian children >10 years of age are to be considered overweight if their BMI is >85th percentile for age or if their weight is >120% of the 50th percentile of weight for height by national standards.[24] After reviewing datasets from several populations, WHO found that the NCHS dataset was the most suitable for a smooth transition to the 2006 WHO child growth standard curves at 5 years, and also aligned well with the IOTF cut-off values at the age of 18 years. Accordingly, WHO reconstructed the 1977 NCHS/WHO reference using state-of-the-art statistical analysis, resulting in the development of the 2006 WHO growth reference standards, which is recommended for international use.[4] In our study, 85th and 95th percentile values for

BMI at 18 years in boys are >25 kg/m$^2$ and 31 kg/m$^2$, respectively, while that in girls are >24 kg/m$^2$ and 30 kg/m$^2$, respectively. This indicates that the use of these cut-offs for defining overweight and obesity from the current data will lead to accepting children with a higher BMI (overweight children) as 'normal' at all ages. Thus, we suggest that the 75th percentile value on the current BMI curves may be used as a cut-off for screening for overweight in boys and girls, as also suggested by Khadilkar *et al*.[11]

It is pertinent to point out that there is no uniformity in the methodology adopted by different investigators while creating major growth charts (CDC,[3] Cole *et al.*[16] and WHO[4]). The differences exist mainly in their datasets, age, weight, BMI cut-offs, smoothening methods, adoption of arbitrary assumptions and exclusions. For example, the CDC growth charts have excluded children with very low birth weight. Further, these charts also excluded children above 6 years of age in view of the high prevalence of overweight and obesity observed in the National Health and Nutrition Examination Survey (NHANES) III. CDC has used BMI centiles (85th and 95th) to define overweight and obesity, while Cole *et al*. took values extrapolated to an adult BMI of 25 kg/m$^2$ and 30 kg/m$^2$ for defining overweight and obesity. In view of this, we have not excluded any child on the basis of overweight/obesity while preparing our charts.

In conclusion, this is the largest nationwide study conducted in more than 2 decades, and clearly indicates secular trends in height, weight and BMI in Indian children from the USES. The significant increase in weight implies that using 85th centile of the present data for defining overweight is likely to result in wrongly categorizing overweight and obese children as normal. The limitations of this study include absence of longitudinal data, year-wise grouping of children and pubertal assessment. The significant differences we report compared with earlier Indian studies underscores the need for regular updating of growth charts. In view of the fact that our data are current, nationally representative and include a reference population least likely to have been impacted by environmental growth constraints, we recommend that these data should be used as a growth reference for Indian children and adolescents.

*Conflict of interest:* None

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