Original Article

# Growth Prediction of Under-5 Children Using Statistical Models for Eastern Region of India

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## Abstract

**Background:** Percentile curves are often used to assess variances in children's growth pattern. This study is aimed at explaining effect of the respondents' sociodemographic characteristics on under-5 children's birth weight and identifying most suitable models, out of 11 statistical models reviewed, for estimating children's growth in terms of height and weight of a given birth-weight category and obtain estimated growth curves. **Material and Methods:** The study used National Family Health Survey (NFHS)-4 data from four Eastern States of India, consisting of 54,075 under-5 children. Estimated growth curves were obtained, using best-fit models. **Results:** Birth weight was found to be associated with children's age, gender, birth order, body mass index, mother's education, living place and wealth index. Two models – *Cubic Model and Power Model* – showed best fit to the height and weight measurements. We obtained estimated growth curves of boys and girls for a given birth-weight category. **Conclusions:** All socio-demographic factors studied, except respondent's occupation, were associated with children's birth weight. *Cubic and Power Models* were most suitable for assessing growth in terms of height and weight of boys and girls, belonging to a given birth-weight category.

**Keywords:** Anthropometry, birth weight, child growth, statistical models, under-5 children

## Introduction

Childhood, characterized by growth, is basically a physiological process.[1] Growth trajectories provide essential indicators for child development and act as potential determinants of adult health outcomes.[2] Growth charts are frequently used as an important tool for measuring children's growth and their nutritional status.[3] Several countries have created their own growth references, taking into account racial and ethnic varieties and environmental variables in human growth across the world.[3] In general pediatric practice, measurements, such as length/height and weight are widely acknowledged in child growth and development. Their comparison to national or international growth references is often done to determine variations in their growth patterns.[4] WHO Growth References for children, aged 0–5 years, as well as for children and adolescents, aged 5–19 years, were brought-forth sometime back and have been in use since then.[5,6]

In order to study child growth and growth trajectories, mathematical modelling is a powerful tool. It entails fitting models to physical growth data in order to obtain appropriate growth curves provided by children's anthropometric measurements, such as height and weight, even if these are irregularly spaced.[7] Further, nearly 30% of preschool children in impoverished nations have stunted growth as a result of local environmental factors.[8] Indonesian children continue to be among the world's smallest and that stunting is present in them up to 43% of Indonesian districts.[9] Further, as India is going through a nutritional shift, it is critical to keep its growth figures up-to-date.[10] Children's growth patterns in India have been influenced by the country's rapid economic and social transformations. According to a recent Indian study, there is a trend toward increased height, particularly in boys and obesity in both genders.[11] In 2010, Indian Government had approved WHO 2006 Growth Guidelines for measuring growth of children below 5 years of age.[11] In 2019, synthetic

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growth references for Indian children, aged 0–18 years were also released.[12] The present study is aimed at explaining the effect of the respondents' sociodemographic characteristics on their under-5 children's birth weight and identifying most suitable models, out of 11 statistical models reviewed, for estimating growth of children and also, to obtain their estimated growth curves in terms of average height and weight, given their birth-weight categories.

## Material and Methods

The study used data of the India's National Family Health Survey (NFHS)-4. The NFHS-4, a comprehensive survey, collected data on children aged 0–59 months with a variety of demographic and socioeconomic factors and different anthropometric measurements. A total of 2,59,627 children were studied in this survey, and out of these, 54,075 children (28,013 boys and 26,062 girls) belonged to the four states – Bihar, Jharkhand, Odisha, West Bengal. These four states are also called country's Eastern Region. In the present study, we used height and weight data to estimate children's growth. Children were first categorized into four subgroups by their birth weight:(*a*) <2000 gm, (*b*) 2000–2499 gm, (*c*) 2500–2999 gm, and (*d*) 3000 gm+, and then their height and weight curves were obtained, using best-fit models, out of 11 statistical models reviewed.[13]

### Statistical models applied for estimated growth curves and criteria for best-fit models

We carried out statistical analysis, using IBM SPSS 20 Software and Excel. SPSS 20 Software contained only 11 statistical models, and all these models were fitted to the NFHS-4 data on height and weight for boys and girls, considering four birth-weight categories. These 11 statistical models have also been employed for growth estimation of under-5 children of India's Central Region.[13] A model with highest coefficient of determination ($R^2$) was chosen to be the best-fit model. The 11 statistical models, used in the study, are given below.

$(a)$ *Linear Model* : $E(Y_t) = \alpha_0 + \alpha_1 t$

$(b)$ *Logarithmic Model* : $E(Y_t) = \alpha_0 + \alpha_1 \ln(t)$

$(c)$ *Inverse Model* : $E(t) = \alpha_0 + \alpha_1 / t$

$(d)$ *Quadratic Model* : $E(Y_t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2$

$(e)$ *Cubic Model* : $E(Y_t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3$

$(f)$ *Compound Model* : $E(Y_t) = \alpha_0 \alpha_1^t$

$(g)$ *Power Model* : $E(Y_t) = \alpha_0 t^{\alpha_1}$

$(h)$ *S Model* : $E(Y_t) = \exp(\alpha_0 + \alpha_1 / t)$

$(i)$ *Growth Model* : $E(Y_t) = \exp(\alpha_0 + \alpha_1 t)$

$(j)$ *Exponential Model* : $E(Y_t) = \alpha_0 e^{\alpha_1 t}$

$(k)$ *Logistic Model* : $E(Y_t) = \left(\frac{1}{u} + \alpha_o \alpha_1^t\right)^{-1}$

Here, $\alpha_0, \alpha_1, \alpha_2$, and $\alpha_3$ are coefficients and $Y_t$ = observed values, for $t = 1,2,3,....,n$ and $E(Y_t)$ = Expeceted values of $Y_t$.

Our analysis revealed that only two statistical models: (e) *Cubic Model* and (g) *Power Model* best fitted to the height and weight data, considering above 4 birth-weight categories for estimating growth of boys and girls under the age of 5 years.

As explained above, children's birth weight was classified into four categories, namely: (*a*) <2000 gm, (*b*) 2000–2499 gm, (*c*) 2500–2999 gm, and (*d*) 3000 gm+. For purpose of data analysis, we used appropriate filters at different birth-weight categories.

For the weight of boys:

a. At birth weight < 2000 gm,

   *Filter: child's age>*0 *and birth weight*= <2000 *gm and sex of child=male*

b. At birth weight 2000–2499 gm,

   *Filter: child's age>*0 *and birth weight*=2000–2499*gm and sex of child=male*

c. At birth weight 2500–2999 gm,

   *Filter: child's age>*0 *and birth weight*=2500-2999*gm and sex of child=male*

d. At birth weight 3000 gm +

   *Filter: child's age >0 and birth weight = 3000* gm + *and sex of child = male and child weight <40,000* gm

Here, a filter was applied in all four birth-weight groups, that is, in group (a)–(d). However, in group (d) at birth weight 3000 gm +, *child weight* <40,000 gm was added in the filter because extreme values of more than 40,000 gm were to be excluded.

Similarly, for weight of girls,

a. At birth weight <2000 gm,

   *Filter: child" s age>0 and birth weight=<2000 gm and sex of child=female*

b. At birth weight 2000–2499 gm,

   *Filter: child's age>0 and birth weight=2000-2499 gm and sex of child=female*

c. At birth weight 2500-2999 gm,

   *Filter: child' s age>0 and birth weight=2500-2999 gm and sex of child=female*

d. At birth weight 3000 gm +

*Filter: child's age >0 and birth weight = 3000* gm + *and sex of child = female and child weight <40,000* gm

Here also, a filter was applied in all four birth-weight groups, that is, in group (a)–(d). However in group (d) at birth weight 3000 gm + *child weight* <40,000 gm, was added in the filter because extreme values of more than 40,000 gm were to be excluded.

## Results

### Under-5 children's birth weight and sociodemographic characteristics

Table 1 gives distribution of under-5 children by their birth weight and eight sociodemographic characteristics, namely, child age, sex, birth order, body mass index (BMI), respondent's highest educational qualification, respondents' occupation, place of residence, and wealth index. Our analysis showed that birth weight was significantly associated with seven out of eight sociodemographic variables. Thus, birth weight had association with age of child ($\chi^2 = 138.02$, *d.f.* = 12, $P<0.001$),sex of child ($\chi^2 = 97.15$,*d.f.*= 3, $P<0.001$) and birth order ($\chi^2 = 1403.64$, *d.f.*= 9, $P<0.001$). BMI was also found to be significantly associated ($\chi^2$=87.72, *d.f.* = 9, $P<0.001$) with birth weight. When mothers' highest education level and children's birth weight were taken into consideration, our analysis again revealed a strong association between the two factors ($\chi^2 = 1276.73$, *d.f.* = 9, $P<0.001$).. Analysis demonstrated that respondents' two factors – place of residence and wealth index – also play a role in the determination of children's birth weight. This is because respondents' place of residence ($\chi^2 = 212.09$, *d.f.* = 3, $P<0.01$) as well as their wealth index ($\chi^2$=715.77, *d.f.* = 12, $P<0.001$) too exhibited strong association with children's birth weight. Only one factor that did not show any association with children's birth weight was respondents' occupation ($\chi^2 = 11.53$, *d.f.* = 9, $P$=0.241).

### Growth prediction of under-5 children using statistical models

As indicated in the Methods Section, only two models *Cubic Model and Power Model* showed best fit to the height and weight measurements. Thus, for purpose of growth prediction using height and weight curves, results of only two best-fit models have been shown here [Tables 2 and 3].

Table 2 describes model's summary for estimating height of boys and girls separately by birth weight. Here, for height of boys, *Power Model* showed best fit for the birth-weight group <2000 gm ($R^2$ = 0.794) but for the rest of the three birth-weight groups, *Cubic Model* was the best-fit model. Thus, *Cubic Model* showed best fit ($R^2$=0.805) for birth-weight group 2500–2999 gm, followed by 2000-2499 gm ($R^2$=0.787) and then 3000 gm and above ($R^2$ =0.776). Similarly, for height of girls, *Power Model* again showed best fit for the birth-weight group <2000 gm ($R^2$ = 0.820) but for the rest of three birth-weight groups, *Cubic Model* was the best-fit model. Thus, *Cubic Model* showed best fit for birth-weight group 2000-2499 gm ($R^2$ = 0.795), followed by 2500 -2999 gm ($R^2$ = 0.788) and then 3000 gm and above ($R^2$=0.757).

Table 3 describes model's summary for estimating weight of boys and girls separately by birth weights. For the weight of boys as well as girls, best-fit model was the *Power Model*. Further, considering boys, this model fitted best for birth-weight group 2500-2999 gm ($R^2$ = 0.768), followed by 2000-2499 gm ($R^2$ = 0.750), <2000 gm ($R^2$ = 0.746), and then 3000 gm and above ($R^2$=0.733). For estimating weight of girls, *Power Model* showed best-fit for birth-weight group <2000 gm ($R^2$=0.785), followed by 2500-2999 gm ($R^2$ = 0.764), 2000-2499 gm ($R^2$ = 0.762), and then 3000 gm and above ($R^2$ = 0.726).

### Estimated mean height and weight curves and their 95% upper and lower bounds

We calculated growth values for boys and girls separately, based on mean height as well as weight of under-5 children for age ranging from 1 to 59 months, taking into account all four birth-weight categories and using either *Cubic* or *Power Models* – wherever these fitted best. Resultantly, mean height and weight curves were produced separately for two sexes, considering all four birth-weight groups. Figures 1(a)–(d) presents estimated mean height and weight curves of boys for all four birth-weight groups. Similarly, such estimated mean height and weight curves for girls for all four birth-weight groups are shown in Figures 2(a)–(d). The graphs shown, besides giving estimated mean height and mean weight curves also give curves for 95% upper as well as lower bounds. Thus, using curves of Figures 1(a)–(d) and Figure 2(a)–(d), it is possible to derive not only the expected average growth values of under-5 children in terms of their mean height and mean weight for their ages but also their 95% upper and lower bounds in each case.

## Discussion

As our country is going through a nutritional transition, it is critical to keep track on growth of children on regular basis. Growth is not only considered as an indicator of health but also its secular trend demonstrates level of the population health. In growth studies, we often make use of growth standards and growth references. Growth standards define how a child population should grow, given optimal nutrition as well as optimal health, whereas growth references are descriptive in nature and are prepared from a population which is thought to be growing and keeping best possible nutrition and health.[10] As children's growth patterns alter over time, their growth references should also be revised from time to time.

Children's birth weight is regarded as an important parameter of their health. Protein energy malnutrition has been found to be its predictor.[14] For the assessment of new-borns' survival and development, birth weight is frequently regarded as a single important factor. For India, we analyzed NFHS-4 data of under-5 children from four states – Bihar, Jharkhand, Odisha, and West Bengal, to investigate the association between children's selected sociodemographic variables and birth weights. Our analysis demonstrated a significant association of birth weight

**Table 1: Under-5 children of different birth-weight categories by their sociodemographic characteristic in Eastern Region of India**

| Sociodemographic Characteristics | Birth weight (gm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | < 2000 | | 2000-2499 | | 2500-2999 | | 3000+ | | Total |
| | $n_1$ | % | $n_2$ | % | $n_3$ | % | $n_3$ | % | $n$ |
| Child Age (Months) | | | | | | | | | |
| <12 | 284 | 2.6 | 1020 | 9.5 | 3010 | 27.9 | 6472 | 60 | 10,786 |
| 12-23 | 295 | 3.1 | 938 | 9.8 | 2617 | 27.3 | 5728 | 59.8 | 9578 |
| 24-35 | 249 | 2.5 | 930 | 9.3 | 2748 | 27.4 | 6087 | 60.8 | 10,014 |
| 36-47 | 242 | 2.3 | 884 | 8.4 | 2660 | 25.3 | 6716 | 63.9 | 10,502 |
| 48-59 | 260 | 2.6 | 754 | 7.5 | 2410 | 24.1 | 6585 | 65.8 | 10,009 |
| $\chi^2(d.f.=12)=138.020, p<0.001$ | | | | | | | | | |
| Sex of Child | | | | | | | | | |
| Boy | 713 | 2.5 | 2316 | 8.3 | 6923 | 24.7 | 18061 | 64.5 | 28,013 |
| Girl | 824 | 3.2 | 2482 | 9.5 | 6974 | 26.8 | 15782 | 60.6 | 26,062 |
| $\chi^2(d.f.=3)=97.151, p<0.001$ | | | | | | | | | |
| Birth Order | | | | | | | | | |
| 1 | 777 | 4.1 | 2059 | 11 | 5807 | 30.9 | 10126 | 54 | 18,769 |
| 2 | 389 | 2.5 | 1348 | 8.5 | 4275 | 27.1 | 9765 | 61.9 | 15,777 |
| 3 | 192 | 2 | 710 | 7.5 | 2102 | 22.3 | 6425 | 68.1 | 9429 |
| 4 & above | 179 | 1.8 | 681 | 6.7 | 1713 | 17 | 7527 | 74.5 | 10,100 |
| $\chi^2(d.f.=9)=1403.64, p<0.001$ | | | | | | | | | |
| BMI (kg/m$^2$) | | | | | | | | | |
| < 18.5 | 562 | 3.4 | 1677 | 10 | 4393 | 26.3 | 10,080 | 60.3 | 16,712 |
| 18.5-24.9 | 825 | 2.6 | 2722 | 8.4 | 8204 | 25.4 | 20,550 | 63.6 | 32,301 |
| 25.0-29.9 | 105 | 2.9 | 307 | 8.3 | 964 | 26.2 | 2304 | 62.6 | 3680 |
| ≥ 30 | 28 | 3.5 | 53 | 6.7 | 205 | 26 | 503 | 63.8 | 789 |
| $\chi^2(d.f.=9)=87.723, p<0.001$ | | | | | | | | | |
| Respondent's Highest Educational Level | | | | | | | | | |
| No Education | 516 | 2.2 | 1768 | 7.5 | 4646 | 19.7 | 16694 | 70.7 | 23624 |
| Primary | 233 | 3.1 | 715 | 9.5 | 2013 | 26.8 | 4542 | 60.5 | 7503 |
| Secondary | 692 | 3.4 | 2080 | 10.3 | 6413 | 31.6 | 11085 | 54.7 | 20,270 |
| Higher | 96 | 3.6 | 235 | 8.8 | 825 | 30.8 | 1522 | 56.8 | 2678 |
| $\chi^2(d.f.=9)=1276.732, p<0.001$ | | | | | | | | | |
| Respondent's Occupation | | | | | | | | | |
| No Occupation | 207 | 3 | 625 | 9 | 1855 | 26.6 | 4291 | 61.5 | 6978 |
| Others | 28 | 3.2 | 89 | 10.1 | 229 | 26.1 | 531 | 60.5 | 877 |
| Agriculture | 17 | 1.9 | 80 | 8.8 | 214 | 23.6 | 595 | 65.7 | 906 |
| Don't Know | 2 | 2 | 8 | 7.9 | 23 | 22.8 | 68 | 67.3 | 101 |
| $\chi^2(d.f.=9)=11.531, p<0.241$ | | | | | | | | | |
| Place of Residence | | | | | | | | | |
| Urban | 272 | 3.5 | 771 | 9.8 | 2462 | 31.3 | 4349 | 55.4 | 7854 |
| Rural | 1265 | 2.7 | 4027 | 8.7 | 11,435 | 24.7 | 29,494 | 63.8 | 46,221 |
| $\chi^2(d.f.=3)=212.092, p<0.001$ | | | | | | | | | |
| Wealth Index | | | | | | | | | |
| Poorest | 648 | 2.4 | 2162 | 8.1 | 5746 | 21.6 | 18,085 | 67.9 | 26,641 |
| Poorer | 427 | 3.2 | 1309 | 9.7 | 3739 | 27.8 | 7982 | 59.3 | 13,457 |
| Middle | 236 | 3.1 | 703 | 9.3 | 2362 | 31.3 | 4256 | 56.3 | 7557 |

*Contd...*

**Table 1: Contd...**

| Sociodemographic Characteristics | Birth weight (gm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | < 2000 | | 2000-2499 | | 2500-2999 | | 3000+ | | Total |
| | $n_1$ | % | $n_2$ | % | $n_3$ | % | $n_3$ | % | $n$ |
| Richer | 155 | 3.5 | 463 | 10.4 | 1417 | 31.8 | 2421 | 54.3 | 4456 |
| Richest | 71 | 3.6 | 161 | 8.2 | 633 | 32.2 | 1099 | 56 | 1964 |

$\chi^2(d.f.=12) = 715.770, p < 0.001$

**Table 2: Model's summary for height of boys and girls by their birth-weight categories: NFHS-4 (2015-16)**

| Birth weight (gm) | Model | $R^2$ | Constant | d.f.* | | F | $b_1$ | $b_2$ | $b_3$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Regression | Residuals | | | | |
| Boys | | | | | | | | | |
| < 2000 | Power | 0.794 | 45.357 | 1 | 580 | 2236.670 | 0.186 | - | - |
| 2000-2499 | Cubic | 0.787 | 53.988 | 3 | 2110 | 2600.162 | 1.766 | -0.33 | 0.0002 |
| 2500-2999 | Cubic | 0.805 | 54.833 | 3 | 6505 | 8934.308 | 1.701 | -0.029 | 0.0002 |
| 3000 + | Cubic | 0.776 | 56.535 | 3 | 16,343 | 18,908.822 | 1.586 | -0.027 | 0.0002 |
| Girls | | | | | | | | | |
| < 2000 | Power | 0.820 | 44.030 | 1 | 707 | 3228.263 | 0.190 | - | - |
| 2000-2499 | Cubic | 0.795 | 53.413 | 3 | 2265 | 2936.483 | 1.666 | -0.029 | 0.0002 |
| 2500-2999 | Cubic | 0.788 | 54.647 | 3 | 6557 | 8146.196 | 1.588 | -0.025 | 0.0001 |
| 3000+ | Cubic | 0.757 | 55.537 | 3 | 14,329 | 14,846.329 | 1.530 | -0.025 | 0.0001 |

Note: *d.f.: – degree of freedom

**Table 3: Model's summary for weight of boys and girls by birth-weight categories: NFHS-4 (2015-16)**

| Birth weight (gm) | Model | $R^2$ | Constant | *d.f. | | F | $b_1$ |
|---|---|---|---|---|---|---|---|
| | | | | Regression | Residuals | | |
| Boys | | | | | | | |
| < 2000 | Power | 0.746 | 2742.468 | 1 | 581 | 1709.032 | 0.393 |
| 2000-2499 | Power | 0.750 | 3276.688 | 1 | 2115 | 6337.666 | 0.345 |
| 2500-2999 | Power | 0.768 | 3430.093 | 1 | 6515 | 21,606.757 | 0.339 |
| 3000 + | Power | 0.733 | 3747.194 | 1 | 16356 | 44,832.622 | 0.316 |
| Girls | | | | | | | |
| < 2000 | Power | 0.785 | 2546.490 | 1 | 707 | 2573.891 | 0.396 |
| 2000-2499 | Power | 0.762 | 3066.895 | 1 | 2268 | 7255.047 | 0.350 |
| 2500-2999 | Power | 0.764 | 3277.480 | 1 | 6566 | 21,286.691 | 0.338 |
| 3000 + | Power | 0.726 | 3391.454 | 1 | 14335 | 38,065.486 | 0.329 |

Note: *d.f.: – degree of freedom

with age and sex of the children, their birth order, BMI, mother's highest level of education, place of residence, and wealth index. In a cross-sectional study by *Borah and Agrawala*[15] carried out in a rural block of the Assam State (India), illiterate teenage mothers, grand multipara mothers with short interpregnancy intervals, and anemic mothers found to be risk factors of the low birth weight. Another study by *Mishra et al*.[16] demonstrated that underweight rural women and those with no or primary education, low BMI, households with unclean cooking fuel, and women from Northern and Eastern regions of the country had higher share of low birth weight.

Statistical modelling approach in growth studies is a strong tool for analyzing children's growth and trajectories. It allows one to create appropriate growth curves by fitting models to physical growth data. Our results demonstrated that, out of 11 models applied, only two models – *Cubic Model and Power Model* – showed best fit, considering measurements of height and weight of under-5 children. These models allowed us to obtain mean height and weight of boys and girls as a function of age for different birth-weight categories, as well as their 95% upper and lower bounds. The estimated growth curves are likely to be quite useful in predicting average height and weight of under-5 children by age for a given birth-weight category.

One rationale which is often given for using modelling approach to growth data is that a suitable curve will neatly encapsulate the information offered by an individual child's

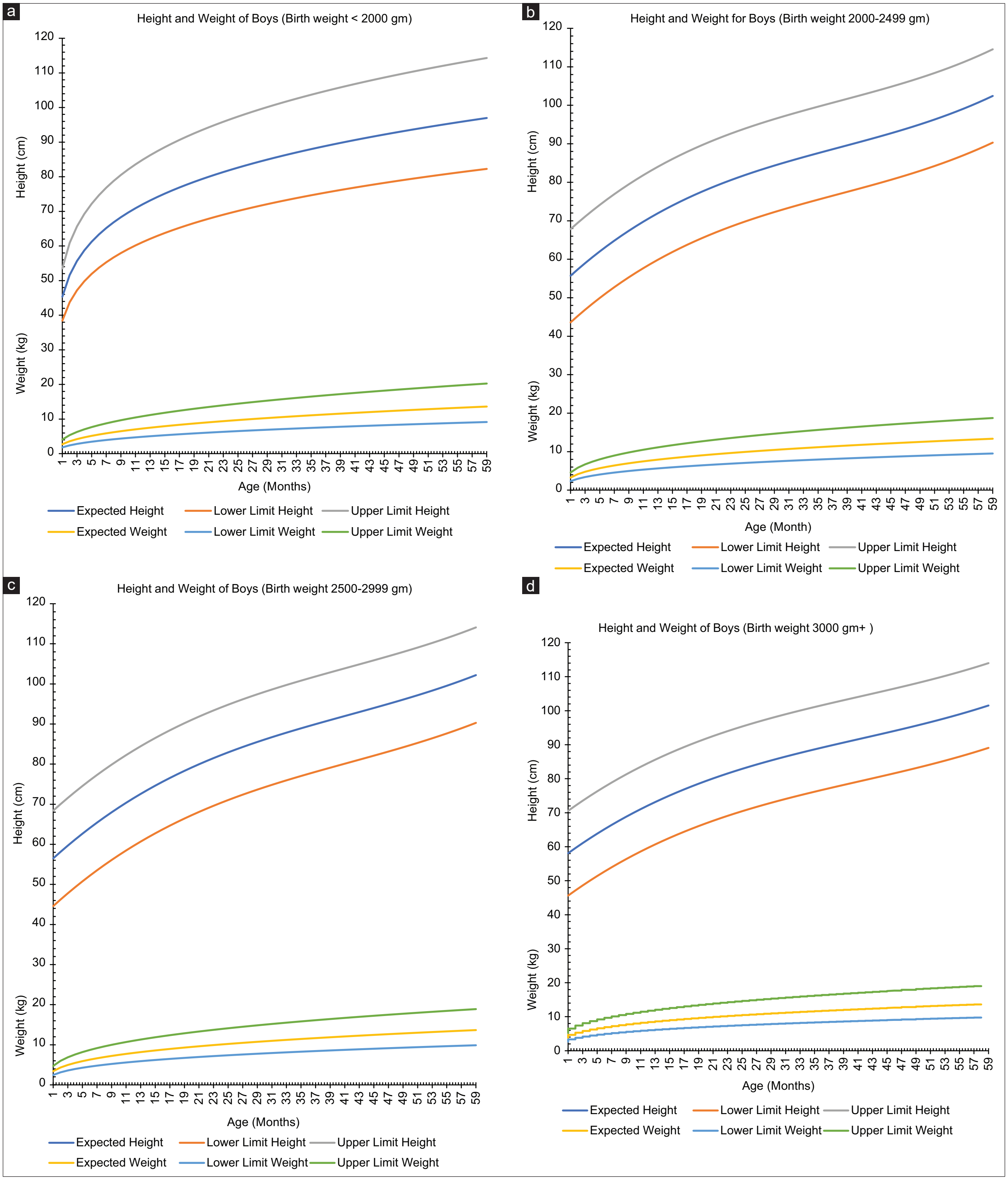


**Figure 1:** (a) Estimated mean height &and weight curves of boys,using the Power Model in Eastern Region (India): NFHS--4 (Birth -weight<2000 gm). (b) Estimated mean height and weight curves of boys using the Cubic and Power Models respectively in Eastern Region (India): NFHS-4 (Birth weight 2000–2499 gm). (c) Estimated mean height and weight curves of boys, using the Cubic and Power Models, respectively, in Eastern Region (India): NFHS-4 (Birth weight 2500–2999 gm). (d) Estimated mean height and weight curves of boys, using Cubic and Power Models, respectively, in Eastern Region (India): NFHS-4 (Birth weight 3000 gm+)

observations. In addition, statistical models also generate smooth curves of status as well as of velocity – even from irregularly spaced measurements. Furthermore, by using parametric estimates, one can have more estimates

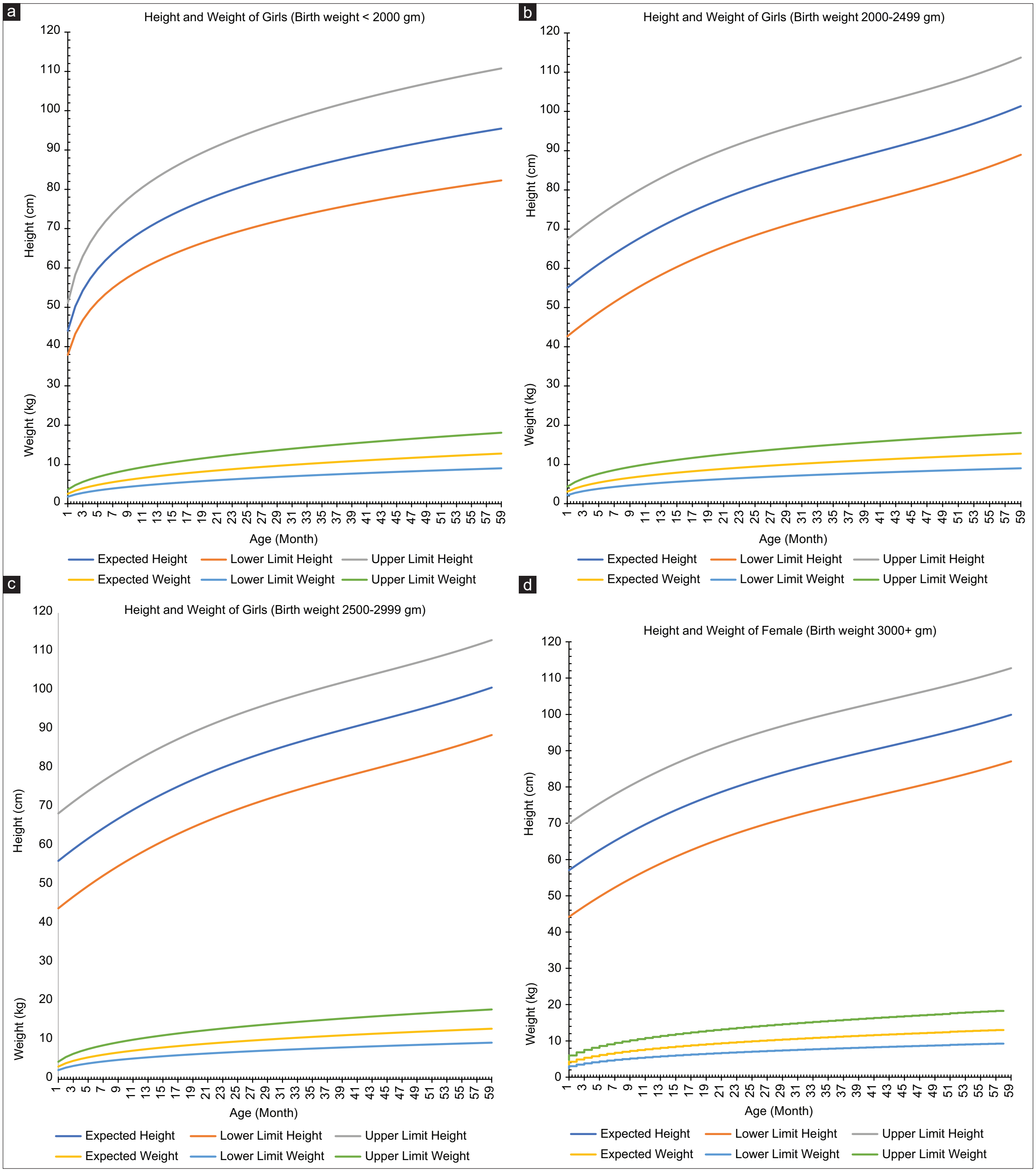


**Figure 2:** (a) Estimated mean height and weight curves of girls, using Power Model in Eastern Region (India): NFHS-4 (Birth weight <2000 gm). (b) Estimated mean height and weight curves of girls, using Cubic and Power Models respectively in Eastern Region (India): NFHS-4 (Birth weight 2000–2499 gm). (c) Estimated mean height and weight curves for girls, using the Cubic and Power Models, respectively: NFHS-4 (Birth weight 2500–2999 gm).(d) Estimated mean height and weight curves of girls, using the Cubic and Power Models, respectively, in Eastern Region (India): NFHS-4 (Birth weight 3000 gm +)

for families of curves. The Jenss–Bayley Model have demonstrated best fit for height and weight, both for boys and girls.[7] The authors also found that mean height growth trajectories were identical in shape and direction for boys as well as for girls, while the mean weight growth curve of girls fell slightly below the curve of boys after their neonatal life.[7] Berkey[17] in 1982 compared two statistical models, namely, Count Model – a linear model, and the Jenss Model – a nonlinear model, for growth in terms of length and weight of the preschool children in United States. Author fitted these models to a large amount of data on length and weight and results were used to study efficiency, reliability, and goodness-of-fit of the models. The author showed that the Count Model did not adequately fit to the data, while the Jenss Model fitted to the data very well for both length and weight of the pre-school children.

Country's rapid economic and social transition had an impact on children's growth patterns in India.[10] According to some Indian studies,[11,12] there is a trend toward increasing height, especially among boys, as well as an increase in obesity among both sexes. In the present study, we used NFHS-4 data for the Eastern Region of India. These data have been utilized for estimating growth curves of under-5 children, considering mean height and weight for boys and girls separately for different birth-weight categories, applying *Cubic Model and Power Model*. In fact, several factors may play a role, including the quality of data used, in the goodness of fit of any model. As explained above, NFHS-4 data used in this study belong to the Government Department, and so, these should be of high quality.

## Conclusions

Sociodemographic factors – age and sex of child, birth order and BMI, and mother's highest level of education, their place of residence, and wealth index – were significantly associated with the birth weight of the under-5 children. Two statistical models – *Cubic Model and Power Model* – were found to be most suitable for estimating child growth curves in terms of mean height and weight of boys and girls – considering their specific birth-weight category. Estimated growth charts of mean height and weight of under-5 boys and girls are likely to be quite useful in the context of Indian growth studies, particularly from its Eastern Region.

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### Conflicts of interest

There are no conflicts of interest.

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