Secular trends in height in different states of India in relation to socioeconomic characteristics and dietary intakes

Raja Sriswan Mamidi, Bharati Kulkarni, and Abhishek Singh

Abstract

Background. *Information on adult height and associated secular trends in relation to socioeconomic characteristics based on a nationally representative sample is not available from India.*

Objective. *To assess the average adult height and secular trends in height in different states of India in relation to socioeconomic characteristics and dietary intakes according to data from the Third National Family Health Survey (NFHS 3).*

Methods. *Average heights and associated secular trends were analyzed for each state and in relation to socioeconomic variables. Bivariate and multiple regression analyses were performed to examine the association of socioeconomic factors and consumption of animal-source foods with height.*

Results. *Data from anthropometric measurements were available for 69,245 men and 118,796 women in the age group from 20 to 49 years. The average heights of adult men and women were 165 and 152 cm, respectively, with wide variation among states. Overall, there was a modest secular increase in height (0.50 cm per decade in men and 0.22 cm per decade in women), with a negative secular trend in some of the states. There were striking regional differences in the average heights and the secular trends in height. Similarly, higher socioeconomic status was associated with greater height and a greater secular increase in height. Milk consumption had a positive association with height in men (*$r = 0.69$, $p < .001$*) and women (*$r = 0.63$, $p < .001$*) in various/different states.*

Conclusions. *The secular increase in height has been modest in India in spite of impressive economic growth. Consumption patterns of milk in different states may be related to the regional differences in height.*

Key words: Animal-source foods, height, Indian population, secular trend

Introduction

A secular trend in increase in height has been observed in developed countries since the late 19th century, mainly due to improvement in nutritional status as a result of socioeconomic development [1–4]. According to Tanner, growth of a population is a mirror that reflects conditions in society [5].

There has been intense research interest in the area of linear growth in developing countries, including India, because shorter height is associated with a number of consequences, such as poor cognitive development [6], obstetric emergencies [7], and low birthweight in the offspring of short women [8]. In addition, low-birthweight babies are more likely to suffer from growth faltering and become stunted adults, and thus the cycle of growth retardation is repeated [9]. Secular changes in the height of adults in India, however, have not been adequately studied. A few studies from different parts of the country that assessed secular trends in height in small samples had varying results [10, 11], but the average height of the population and associated secular trends in height based on a nationally representative sample have not been reported.

The absence of high-quality anthropometric data obtained over long periods of time may be an important reason for the lack of information on secular trends in India. To overcome a similar difficulty, a number of studies from other countries have compared the heights of adults in different age groups in cross-sectional samples that represent cohorts born at different time points [12–14]. A study in Brazil validated the estimation of secular changes in child growth using this

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approach in a cross-sectional sample by comparing the estimates with those obtained using different data sets collected at two time points. The results indicated that these two methods provided comparable estimates of the secular changes in height [15].

In the present study, we examined secular trends in adult height using data from the Third National Family Health Survey (NFHS 3), which were obtained from a large, nationally representative sample of the population in several states in India. The age group from 20 to 49 years was chosen for these analyses because linear growth is complete and adult height is attained by the age of 20 years, even in undernourished populations [16], and height may be relatively stable until the end of the fifth decade when the age-related loss of height begins. We also examined average height and secular changes in height in relation to a number of socioeconomic variables collected during this survey, including place of residence (urban or rural), education, wealth, religion, caste, and dietary intake of animal-source foods, as these may have direct or indirect influences on the height of an individual.

Methods

Data collection

NFHS-3 provides information related to fertility, health, and nutrition collected from a nationally representative, cross-sectional sample from all states in India. NFHS-3 adopted a two-stage sample design in rural areas and a three-stage sample design in urban areas. In each state, the rural sample was selected in two stages: the first stage involved selection of primary sampling units (PSUs), i.e., villages, with probability proportional to population size (PPS); the second stage involved the systematic selection of households within each PSU. The basic reason for adopting a three-stage sample design in urban areas is that urban wards are quite large, making it difficult to list all the households in a ward and select households directly from the resulting list. Hence, in urban areas wards were selected with PPS sampling in the first stage. In the next stage, one census enumeration block (CEB) was selected by PPS from each selected ward, and in the final stage, households were randomly selected from each selected CEB [17]. Data were collected by structured interviews with men and women aged 15 to 49 years. Anthropometric measurements were performed in preschool children and in women and men 15 to 49 years of age. Height was recorded to the nearest 0.1 cm with an anthropometric rod, and weight was measured to the nearest 10 g with a solar-powered electronic weighing scale. Dietary intakes were estimated from food-frequency questionnaires. The respondent was asked whether he or she consumed foods such as milk, fish, eggs, and meat daily, weekly, occasionally, or never. Data from the survey are available free of cost from MEASURE-DHS (www.measuredhs.com). Data files were accessed with permission.

Data from anthropometric measurements were available for 69,245 men and 118,796 women. Average heights were analyzed separately for each state and in relation to socioeconomic characteristics, such as place of residence, education, religion, caste, and wealth index in the age groups 20 to 29, 30 to 39, and 40 to 49 years. The wealth index was calculated on the basis of data on 33 household assets and housing characteristics, such as ownership of consumer items, type of dwelling, source of water, and availability of electricity, which were then combined into a single wealth index with the use of a scientific method of assigning weights to individual components. The household population was then divided into five equal groups from poorest to richest [18].

Statistical analysis

All analyses were performed with SPSS for Windows, version 17. National weights and state weights were used for analyzing country- and state-level data, respectively. Data are presented as means and standard deviations. For the assessment of secular trends in different states and various socioeconomic categories, simple linear regression analyses were performed for men and women aged from 20 to 49 years. Height was used as the dependent variable and age as the independent variable. The constant of the regression model was considered to be the predicted height at age 20. The beta coefficient of the model indicates the change in height per year. This was multiplied by 10 to estimate the increments in height per decade from the older to the younger generation. Since the highest increments in height were found in the state of Kerala (for both men and women) and the lowest in Meghalaya (for men only), these two states were chosen as an example of opposite secular trends in height. Line graphs of the heights of men and women in relation to age are presented for these two states. Consumption of animal-source foods was recoded to at least once a week (daily or weekly) and less than once a week (occasionally or never). To explore the relationship between intake of animal-source foods and average height, Pearson's correlation coefficient was calculated for animal-source food intake (percentage of population consuming animal-source foods at least once a week) and the mean height of men and women in various states. Multiple regression analysis was performed with height as the dependent variable and age of the respondent, region (states grouped in six regions as shown in **tables 1** and **2**), socioeconomic variables (place of residence, wealth index, educational level, religion, caste), and dietary intakes (consumption of milk, eggs, fish, and

TABLE 1. Mean height (cm) of men aged 20 to 29, 30 to 39, 40 to 49, and 20 to 49 years, predicted height at age 20 years, and increment in height per decade for India and states, 2005/06

	20–29 yr			30–39 yr			40–49 yr			20–49 yr			Predicted height at age 20	Increment/ decade	p
State	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N			
North															
Jammu and Kashmir	168.0	6.8	307	166.6	7.4	250	165.8	7.8	161	167.0	7.3	719	170.2	0.99	< .001
Himachal Pradesh	166.4	6.8	260	165.1	7.3	266	165.1	6.0	205	165.5	6.8	731	168.3	0.82	< .01
Punjab	168.4	6.5	422	169.0	6.8	288	168.5	7.1	245	168.6	6.8	955	168.4	–0.06	.810
Uttaranchal	165.2	6.5	252	164.8	6.1	258	164.6	5.7	172	164.9	6.2	682	166.1	0.37	.208
Haryana	168.1	6.9	350	168.4	6.5	250	167.6	6.0	200	168.1	6.5	800	168.5	0.13	.632
Delhi	165.9	7.1	372	165.4	5.9	191	166.3	6.2	154	165.8	6.6	718	165.8	–0.02	.933
Rajasthan	167.2	6.8	455	167.5	6.5	345	166.7	6.8	275	167.2	6.7	1,075	167.9	0.23	.346
Central															
Chhattisgarh	163.7	6.3	395	163.5	6.1	377	162.7	6.2	263	163.4	6.2	1,034	164.9	0.46	.051
Madhya Pradesh	165.8	6.7	827	165.5	6.4	701	165.5	6.6	553	165.6	6.5	2,081	165.9	0.07	.683
Uttar Pradesh	164.5	6.6	3,242	164.2	6.4	2,547	163.9	6.5	1,870	164.3	6.5	7,659	165.1	0.25	< .01
Northeast															
Sikkim	160.0	7.7	292	160.8	6.4	178	158.1	6.7	128	159.8	7.2	598	162.6	0.90	< .05
Arunachal Pradesh	161.0	6.0	223	161.8	5.7	173	162.8	7.2	116	161.7	6.2	511	159.4	–0.71	< .005
Nagaland	163.1	6.1	1,242	163.0	6.1	947	162.8	6.2	729	163.0	6.1	2,918	163.3	0.11	.421
Manipur	163.4	6.0	1,198	163.1	6.0	962	163.1	5.9	716	163.2	6.0	2,875	163.9	0.21	.118
Mizoram	162.9	5.9	227	161.8	6.1	163	162.3	5.5	127	162.4	5.9	518	164.6	0.66	< .05
Tripura	161.6	6.0	211	161.7	5.8	177	161.3	6.4	141	161.5	6.0	529	162.1	0.17	.569
Meghalaya	157.5	6.4	210	157.9	6.4	148	158.7	6.1	98	157.9	6.3	456	155.6	–0.73	< .05
East															
Assam	163.3	7.1	375	163.2	6.5	339	162.5	6.5	260	163.0	6.7	974	164.4	0.42	.112
West Bengal	163.8	6.7	779	163.5	6.1	666	161.9	6.2	571	163.2	6.4	2,016	166.3	0.96	< .001
Jharkhand	162.5	6.2	262	162.5	6.7	249	162.6	6.3	196	162.5	6.4	707	162.4	–0.05	.856
Orissa	162.9	5.9	440	162.8	6.2	420	163.0	6.8	319	162.9	6.3	1,178	162.8	–0.05	.836
Bihar	163.6	7.2	336	163.1	6.7	307	163.3	6.1	239	163.4	6.7	883	163.8	0.14	.616
West															
Goa	165.3	6.8	308	165.2	6.7	311	163.8	6.8	232	164.9	6.8	851	167.7	0.83	< .01
Gujarat	166.2	6.9	413	165.6	6.2	363	164.9	6.6	294	165.7	6.6	1,069	167.5	0.55	< .05
Maharashtra	165.7	6.8	2,566	165.2	6.4	2,123	163.7	6.8	1,478	165.1	6.7	6,167	168.1	0.95	< .001
South															
Andhra Pradesh	164.6	6.5	2,133	164.4	6.8	1,817	163.4	6.4	1,457	164.2	6.6	5,407	165.9	0.53	< .001
Karnataka	165.7	7.1	1,520	165.3	6.7	1,336	164.6	6.8	987	165.3	6.9	3,842	167.2	0.57	< .001
Kerala	167.8	6.9	279	166.1	6.8	283	165.9	6.7	258	166.6	6.9	820	170.0	0.99	< .001
Tamil Nadu	165.5	6.8	1,657	164.5	6.5	1,466	163.8	6.5	1,326	164.6	6.7	4,449	167.5	0.84	< .001
India	165.2	6.9	21,394	164.7	6.6	18,029	164.1	6.7	14,082	164.7	6.8	53,506	166.3	0.50	< .001

TABLE 2. Mean height (cm) of women aged 20 to 29, 30 to 39, 40 to 49, and 20 to 49 years, predicted height at age 20 years, and increment in height per decade for India and states, 2005/06

State	20–29 yr			30–39 yr			40–49 yr			20–49 yr			Predicted height at age 20	Increment/ decade	*p*
	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*			
North															
Jammu and Kashmir	154.7	5.9	1,133	154.5	5.7	784	153.8	6.1	553	154.4	5.9	2,470	155.7	0.39	< .01
Himachal Pradesh	153.8	5.7	1,063	153.7	5.6	903	153.4	5.5	640	153.7	5.6	2,605	154.5	0.24	.066
Punjab	154.7	6.1	1,292	154.5	5.6	967	154.7	5.6	711	154.7	5.9	2,970	154.7	0.00	.986
Uttaranchal	153.0	5.6	984	152.8	5.4	791	152.3	5.8	511	152.7	5.6	2,285	153.8	0.32	< .05
Haryana	154.8	6.1	944	155.0	5.6	762	155.1	5.8	496	154.9	5.9	2,201	154.5	−0.12	.436
Delhi	153.7	6.6	880	154.1	6.4	740	154.3	6.5	499	154.0	6.5	2,118	153.0	−0.31	.071
Rajasthan	154.5	6.2	1,315	154.5	5.6	1,002	154.6	6.0	739	154.5	6.0	3,056	154.5	0.00	.985
Central															
Chhattisgarh	151.6	5.8	1,266	151.5	5.8	1,003	150.6	5.3	676	151.3	5.7	2,945	153.0	0.51	< .001
Madhya Pradesh	152.5	5.6	2,189	152.8	5.5	1,682	152.5	5.5	1,271	152.6	5.5	5,141	152.4	−0.06	.494
Uttar Pradesh	150.7	5.7	3,769	150.9	5.6	2,919	150.5	5.7	1,741	150.7	5.7	8,429	150.9	0.05	.551
Northeast															
Sikkim	151.4	5.6	760	151.5	5.5	551	150.1	5.8	335	151.2	5.7	1,645	152.4	0.40	< .001
Arunachal Pradesh	150.9	5.6	579	151.1	5.3	445	150.8	5.5	213	151.0	5.5	1,238	151.2	0.07	.732
Nagaland	152.6	5.3	1,474	152.9	5.7	1,039	153.1	5.6	575	152.8	5.5	3,089	152.0	−0.27	< .05
Manipur	152.1	5.1	1,557	151.9	5.2	1,263	151.6	5.1	803	151.9	5.1	3,624	152.9	0.31	< .05
Mizoram	152.0	5.0	636	151.5	5.1	512	151.8	5.5	329	151.8	5.2	1,477	152.1	0.11	.500
Tripura	150.1	5.9	588	149.6	5.6	494	149.3	5.7	377	149.7	5.8	1,458	151.0	0.40	< .05
Meghalaya	149.3	6.2	743	149.2	5.1	480	149.4	5.8	318	149.3	5.8	1,541	148.9	−0.14	.438
East															
Assam	150.6	5.6	1,370	150.5	5.5	1,060	150.4	5.9	569	150.5	5.6	2,999	150.7	0.06	.647
West Bengal	151.0	5.4	2,298	150.7	5.6	1,841	150.5	5.4	1,265	150.8	5.5	5,405	151.7	0.28	< .01
Jharkhand	150.0	5.4	1,022	150.3	5.8	769	149.6	5.6	415	150.0	5.6	2,206	150.6	0.19	.213
Orissa	151.0	5.3	1,574	150.9	5.5	1,210	151.1	5.7	774	151.0	5.4	3,558	151.1	0.02	.825
Bihar	150.5	5.4	1,294	150.6	5.6	882	150.4	5.7	638	150.5	5.5	2,815	150.4	−0.04	.731
West															
Goa	152.4	6.5	1,099	152.5	6.1	1,058	152.5	6.3	680	152.5	6.3	2,837	152.2	−0.07	.619
Gujarat	152.7	5.7	1,303	152.6	5.8	1,003	152.2	5.8	722	152.6	5.8	3,028	153.6	0.33	.010
Maharashtra	152.3	6.1	2,948	151.9	5.8	2,390	151.3	5.9	1,439	151.9	5.9	6,778	153.7	0.57	< .001
South															
Andhra Pradesh	152.1	5.7	2,507	151.7	5.7	1,825	150.9	5.9	1,415	151.7	5.8	5,747	153.3	0.51	< .001
Karnataka	152.7	6.0	1,978	152.8	5.9	1,519	152.1	6.2	1,008	152.6	6.0	4,505	153.3	0.22	.050
Kerala	154.1	6.3	1,053	152.8	6.2	1,088	151.7	6.1	879	152.9	6.3	3,020	157.1	1.24	< .001
Tamil Nadu	153.1	6.1	1,951	152.4	6.3	1,709	151.7	6.1	1,325	152.5	6.2	4,985	154.9	0.72	< .001
India	152.0	5.9	41,348	151.9	5.9	32,250	151.6	6.0	21,973	151.9	5.9	95,571	152.6	0.22	< .001

meat) as independent variables to understand the factors affecting the height of men and women.

Results

Overall, the mean heights of men and women in the age group from 20 to 49 years were 165 and 152 cm, respectively. The mean heights of men and women in different states in the age groups from 20 to 29, 30 to 39, and 40 to 49 years are presented in **tables 1** and **2**. In general, men and women from the northern states were the tallest and those from the northeastern states were the shortest. Interestingly, the younger generation (20 to 29 years) in the state of Kerala appears to be as tall as that in other north Indian states. **Table 1** also indicates predicted height at age 20 based on linear regression and the increments in height per decade. The estimated height at age 20 was highest in the state of Jammu and Kashmir for men (170 cm) and in Kerala for women (157 cm).

When the secular trend in height was analyzed in the total sample, the increments in height for men and women were 0.50 cm per decade ($p < .001$) and 0.22 cm per decade ($p < .001$), respectively. The increment in height was highest in the state of Kerala, where height increased at the rate of 0.99 cm per decade ($p < .001$) among men and 1.2 cm per decade ($p < .001$) among women. Among men, the increment in height was lowest in the state of Meghalaya, where a negative secular trend at a rate of –0.73 cm per decade was found ($p < .05$). Among women, the increment in height was lowest in the state of Nagaland, with a negative secular trend of –0.27 cm per decade ($p < .05$). As the estimated height at age 20 and secular trends among men were highest for the state of Kerala and lowest for Meghalaya, these two states were chosen for comparison of secular trends in height. **Figures 1** and **2** show the average height in relation to age among men and women in these two states. Interestingly, the older generation of both men and women from the states of Kerala and Meghalaya were nearly similar in height, but the younger generation of men and women in Kerala were much taller than their peers from Meghalaya.

Tables 3 and **4** show mean height in relation to different socioeconomic characteristics among men and women of the three age groups. Residence in urban areas, belonging to "other" (forward) castes, higher education, and higher wealth index were associated with greater height in both men and women. The greatest differences were related to wealth index. Differences in height in relation to religion were also apparent, with Sikhs and Jains being taller than people of other religions. Similar relationships were observed between secular trends in height and socioeconomic indicators among men and women, with one or two exceptions.

Table 5 shows the percentage of the population consuming animal-source foods at least once a week in various states. Two distinct regional patterns were observed in the consumption of dairy and other animal-source foods. In general, the percentage of the population consuming milk or curd was highest in the northern states and lowest in the northeastern states. On the other hand, the consumption patterns for other animal-source foods, such as eggs, fish, chicken, and meat, were the opposite, with the highest consumption observed in the northeastern states and the lowest in the northern states. When correlation analyses were carried out between the percentage of the population consuming each of the animal-source foods and height among those in the age group from 20 to 49 years in each state, milk intake had a statistically robust association with height among both men ($r = 0.69$, $p < .001$) (**fig. 3**) and women ($r = 0.63$, $p < .001$) (**fig. 4**). However, there was a negative association between the average height and the percentage of the population

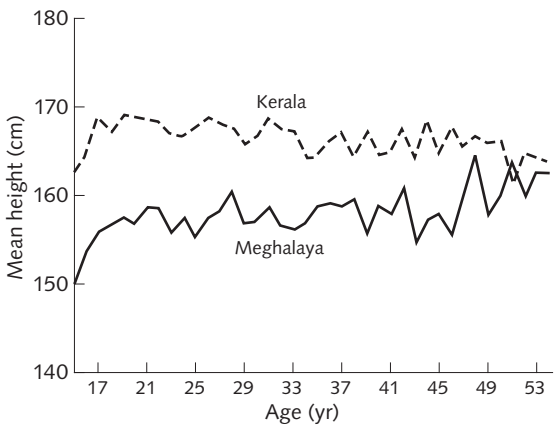

FIG. 1. Secular trend in height among men of Kerala and Meghalaya

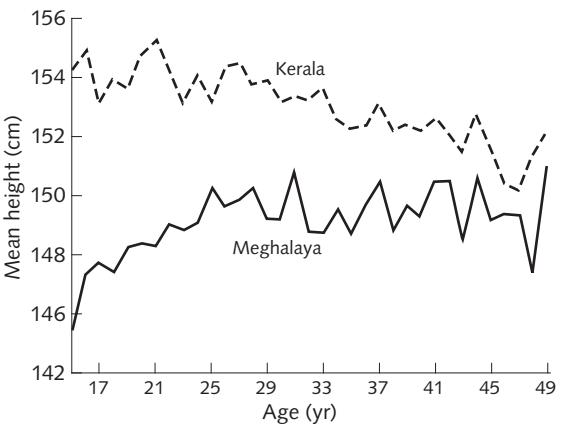

FIG. 2. Secular trend in height among women of Kerala and Meghalaya

TABLE 3. Mean height (cm) of men aged 20 to 29, 30 to 39, 40 to 49, and 20 to 49 years, predicted height at age 20 years, and increment in height per decade in relation to socio-economic indicators 2005/06

	20–29 yr			30–39 yr			40–49 yr			20–49 yr			Predicted height at age 20	Increment/ decade	p
Indicator	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N			
Residence															
Urban	165.9	6.9	7,844	165.5	6.6	6,276	164.7	6.6	4,865	165.5	6.7	18,985	167.3	0.57	< .001
Rural	164.7	6.9	13,550	164.3	6.6	11,753	163.8	6.7	9,217	164.3	6.8	34,521	165.7	0.42	< .001
Education															
No education	163.1	6.5	3,010	163.0	6.7	4,098	162.7	6.8	3,851	162.9	6.7	10,959	163.5	0.16	< .05
Primary	163.3	6.8	3,266	163.7	6.4	3,223	163.3	6.6	3,057	163.4	6.6	9,546	163.5	0.00	.919
Secondary	165.5	6.7	11,622	165.3	6.5	8,136	164.7	6.5	5,518	165.3	6.6	25,276	166.3	0.32	< .001
Higher	167.6	7.0	3,493	167.0	6.2	2,568	166.7	6.4	1,654	167.2	6.6	7,714	168.8	0.50	< .001
Religion															
Hindu	165.1	6.8	17,698	164.6	6.6	14,942	164.0	6.6	11,623	164.6	6.7	44,263	166.3	0.50	< .001
Muslim	165.3	7.0	2,525	164.6	6.3	2,093	164.2	6.7	1,596	164.8	6.7	6,213	166.3	0.47	< .001
Christian	163.8	7.4	442	164.8	6.4	426	164.2	7.3	376	164.3	7.0	1,243	163.9	–0.12	.591
Sikh	170.0	6.4	413	171.0	6.7	288	170.3	6.8	271	170.4	6.6	972	170.2	0.04	.847
Buddhist	164.3	6.9	192	164.1	6.3	160	161.8	5.9	114	163.6	6.5	467	168.0	1.34	< .001
Jain	170.0	5.5	62	168.8	5.3	54	169.0	7.2	43	169.3	5.9	159	173.2	1.15	.050
Wealth index															
Poorest	162.6	6.4	3,041	162.4	6.4	3,202	162.0	6.6	2,451	162.4	6.5	8,694	163.5	0.34	< .001
Poorer	163.8	6.7	3,793	163.7	6.5	3,338	162.9	6.5	2,606	163.5	6.6	9,737	164.8	0.41	< .001
Middle	164.4	6.3	4,673	164.5	6.5	3,578	163.8	6.4	2,805	164.3	6.4	11,056	165.0	0.23	.001
Richer	165.8	6.9	5,123	165.2	6.4	3,880	164.5	6.6	2,869	165.3	6.7	11,872	167.5	0.66	< .001
Richest	167.9	6.9	4,764	167.2	6.5	4,031	166.4	6.5	3,351	167.3	6.7	12,145	169.6	0.71	< .001
Caste															
Scheduled caste	163.8	6.5	4,295	163.2	6.3	3,428	162.2	6.3	2,423	163.2	6.4	10,147	165.2	0.73	< .001
Scheduled tribe	163.0	6.5	1,789	162.8	6.5	1,574	162.2	6.7	1,176	162.7	6.5	4,540	165.6	0.39	.001
Other backward class	165.2	6.8	8,321	164.8	6.5	6,998	164.3	6.4	5,661	164.8	6.6	20,981	164.0	0.45	< .001
Others	166.7	7.0	6,351	166.2	6.7	5,421	165.5	6.8	4,391	166.2	6.9	16,163	166.3	0.56	< .001

TABLE 4. Mean height (cm) of women aged 20 to 29, 30 to 39, 40 to 49, and 20 to 49 years, predicted height at age 20 years, and increment in height per decade in relation to socio-economic indicators 2005/06

	20–29 yr			30–39 yr			40–49 yr			20–49 yr			Predicted height at age 20	Increment/ decade	
Indicator	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*			*p*
Residence															
Urban	152.7	6.0	13,261	152.5	5.9	10,564	152.5	5.9	10,564	152.4	6.0	31,171	153.6	0.35	< .001
Rural	151.7	5.9	28,087	151.7	5.8	21,686	151.7	5.8	21,686	151.6	5.9	64,400	152.2	0.17	< .001
Education															
No education	151.0	5.8	14,799	151.4	5.8	16,236	151.2	6.0	12,321	151.2	5.9	43,356	151.1	−0.03	.324
Primary	151.4	5.7	5,681	151.6	5.8	4,759	151.5	5.9	3,621	151.5	5.8	14,061	151.1	−0.13	< .05
Secondary	152.5	5.9	16,394	152.5	5.7	9,077	152.3	5.8	5,002	152.5	5.8	30,474	152.8	0.09	< .05
Higher	154.5	5.8	4,473	154.5	5.9	2,174	153.8	6.1	1,028	154.4	5.9	7,676	155.1	0.25	< .01
Religion															
Hindu	151.9	5.9	33,386	151.9	5.9	26,160	151.5	5.9	18,161	151.8	5.9	77,707	152.5	0.23	< .001
Muslim	152.2	5.9	5,656	152.0	5.7	4,104	151.9	6.0	2,370	152.1	5.8	12,130	152.7	0.20	< .01
Christian	152.1	6.3	953	152.2	6.5	835	151.8	5.8	640	152.1	6.2	2,428	152.4	0.10	.521
Sikh	155.9	6.0	721	155.5	5.7	622	155.8	5.6	439	155.8	5.8	1,782	156.1	0.10	.550
Buddhist	151.1	6.1	335	150.1	5.3	268	148.6	6.4	180	150.2	6.0	784	154.1	1.20	< .001
Jain	154.5	5.9	106	153.4	5.7	88	153.9	5.7	95	154.0	5.8	289	154.3	0.09	.828
Wealth index															
Poorest	150.6	5.8	7,275	150.7	5.9	6,025	150.6	6.0	3,378	150.6	5.9	16,679	150.7	0.02	.689
Poorer	150.9	5.7	7,731	151.1	5.8	6,220	150.7	5.8	4,003	150.9	5.8	17,954	151.2	0.09	.102
Middle	151.7	5.7	8,360	151.7	5.7	6,407	151.3	5.9	4,366	151.6	5.8	19,133	152.4	0.24	< .001
Richer	152.5	5.8	9,022	152.2	5.6	6,599	151.7	5.9	4,544	152.2	5.8	20,165	153.4	0.39	< .001
Richest	154.1	5.9	8,959	153.8	5.8	6,999	153.0	5.9	5,683	153.7	5.9	21,641	155.4	0.52	< .001
Caste															
Scheduled caste	150.9	5.7	7,800	150.8	5.8	5,927	150.3	5.9	3,969	150.7	5.8	17,695	151.6	0.28	< .001
Scheduled tribe	151.3	5.6	3,433	151.4	5.9	2,630	151.1	5.8	1,622	151.3	5.7	7,686	151.6	0.09	.265
Other backward class	152.0	5.9	16,387	151.9	5.8	12,847	151.5	6.0	8,558	151.8	5.9	37,792	152.7	0.26	.001
Others	153.0	6.0	12,427	152.9	5.9	9,894	152.5	5.9	7,191	152.8	5.9	29,512	153.6	0.24	< .001

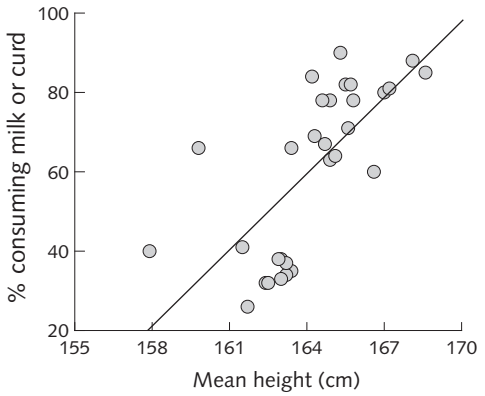

FIG. 3. Scatter diagram showing the percentage of men 20 to 49 years of age in different states consuming milk or curd at least once a week in relation to mean height ($r = 0.69$)

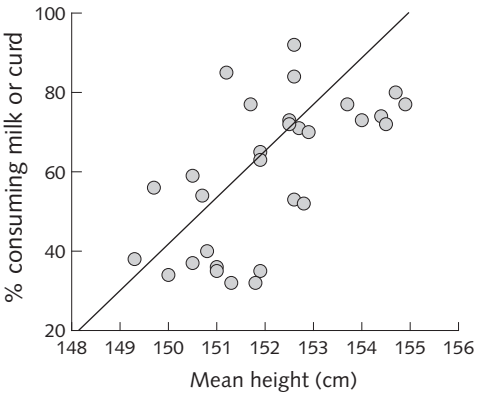

FIG. 4. Scatter diagram showing the percentage of women 20 to 49 years of age in different states consuming milk or curd at least once a week in relation to mean height ($r = 0.63$)

consuming other animal-source foods, such as eggs ($r = –0.44$, $p < .05$ in men; $r = –0.38$, $p < .05$ in women), fish (r = –0.42, $p < .05$ in men; $r = –0.44$, $p = 0.13$ in women), and meat or chicken ($r = –0.49$, $p = < .01$ in men; $r = –0.24$, $p = 0$ .19 in women).

Table 6 represents the multiple regression analysis assessing the relationship of height with the socioeconomic characteristics and dietary intakes of animal-source foods in men and women. The percentage of variation in height explained by the socioeconomic and dietary intake variables was 11% in men and 8% in women**.** The results of the multiple regression analysis confirmed the relationships observed in unadjusted analyses between socioeconomic indicators, such as education, wealth, caste, and religion, and the height of men and women. The regional differences in height persisted after adjustment for other variables in the model. Surprisingly, urban residence was associated with shorter height among both men and women in the multiple regression models. The positive association between milk intake and height persisted after adjustment for the other variables included in the model. Consumption of other animal-source foods was not related to height, except for a negative association of egg consumption with height among men and a positive association between the two in women.

Discussion

The study provides important information on the average heights of Indian adults in a large, nationally representative sample in relation to various socioeconomic characteristics and associated secular trends.

Overall, the average heights of Indian men and women were 165 and 152 cm, respectively, with a modest secular increase of 0.50 and 0.22 cm per decade, respectively. The average height of an Indian man (~ 165 cm) was 11 cm less than the NCHS median height for an 18-year-old adult male (176 cm) and the average height of men reported from other developed countries [19]. From a historical perspective, the average height of Indian men in the 21st century is similar to the height reported for men in many developed countries in the 19th century. Since the end of the 19th century, a secular increase in height has occurred in developed countries, with increments varying from 0.5 to 3 cm per decade [19, 20]. A few studies from India have reported that among well-to-do families, sons are about 4 cm taller than their fathers [11, 21]. It can be speculated that at this rate, even in well-to-do families, the average height of Indian men (165 cm) may take nearly three generations or about 60 years to attain the NCHS median (176 cm). Unfortunately, the high growth rates of the Indian economy are not associated with rapid improvements in the nutritional status of the population.

As environment has a considerable influence on the height of a person, we analyzed height and secular trends in relation to various socioeconomic characteristics (**table 3** and **4**). The largest differences in height of men and women were observed in relation to the state of residence, with men and women from the northern states being tallest and those from the northeastern states shortest. Similar findings have been reported in earlier studies [22, 23]. Though it is difficult to pinpoint the reasons for these differences, wide interstate and regional disparities in socioeconomic indicators, such as level of education, health services, status of women, and nutritional status, may be partly responsible. For example, the highest secular increases in height, which were observed in the state of Kerala, are likely to be a result of the rapid demographic changes that have occurred in the state over the past three decades. The health indicators in this state are far better than those in other states, and the improved health status of the population may have resulted in better linear growth and taller heights in

TABLE 5. Percentage of men and women in the age group from 20 to 49 years consuming animal-source food at least once a week in India and states, 2005/06

State	Men				Women			
	Milk or curd	Egg	Fish	Meat or chicken	Milk or curd	Egg	Fish	Meat or chicken
North								
Jammu and Kashmir	80	31	7	46	74	31	5	58
Himachal Pradesh	82	17	5	11	77	16	10	10
Punjab	85	32	15	19	80	30	11	15
Uttaranchal	78	25	9	14	71	26	14	16
Haryana	88	10	4	6	77	21	14	11
Delhi	78	34	13	22	73	40	22	24
Rajasthan	81	16	3	10	72	23	11	15
Central								
Chhattisgarh	35	37	28	19	32	33	23	18
Madhya Pradesh	71	20	14	10	53	26	19	15
Uttar Pradesh	69	23	10	12	54	25	13	19
Northeast								
Sikkim	66	39	16	42	85	49	34	50
Arunachal Pradesh	26	58	54	46	36	48	56	51
Nagaland	38	44	40	43	52	44	40	43
Manipur	34	43	64	41	35	41	67	21
Mizoram	32	46	20	54	32	36	17	47
Tripura	41	67	83	32	56	69	84	33
Meghalaya	40	59	71	70	38	50	57	61
East								
Assam	33	62	84	42	37	61	75	37
West Bengal	37	67	82	29	40	70	88	29
Jharkhand	32	31	29	19	34	23	23	19
Orissa	38	45	55	26	35	42	57	19
Bihar	66	25	24	19	59	28	20	15
West								
Goa	63	59	89	38	73	45	95	25
Gujarat	82	17	10	9	84	55	42	39
Maharashtra	64	48	34	44	65	54	47	48
South								
Andhra Pradesh	84	75	31	66	77	72	45	70
Karnataka	90	53	25	39	92	61	36	45
Kerala	60	56	88	47	70	51	91	30
Tamil Nadu	78	77	52	54	72	71	52	55
India	67	42	32	29	63	50	45	35

Kerala [24–26]. On the other hand, it is intriguing to observe a negative secular trend in the state of Meghalaya. The majority of the people of Meghalaya (80.5%) belong to scheduled tribes, which represent the lowest stratum of society, and this may be one of the reasons for the negative secular trend [18]. The NFHS 3 report also shows a high prevalence of severe stunting (30%) among children under 5 years of age in Meghalaya [18]. It is possible that stunting of final height in Meghalaya is determined at preschool age.

Studies have indicated that secular trends in height are affected by factors such as place of residence (urban or rural) [27], education, income level [28], and social class [29]. In the present study, people who lived in urban areas, who were more educated, and who belonged to the richest category were taller and had greater increments in height per decade. These associations persisted after adjustment for potential confounders in the multiple regression analyses, except that urban residence had a negative association with height when compared with rural residence (**table 6**). This indicates that the greater height among urban

TABLE 6. Multiple regression assessing the association of men's and women's socioeconomic and dietary habits with their height, 2005/06

	Men			Women		
Variable	B	SE	*p*	B	SE	*p*
(Constant)	164.73	0.17	< .001	153.65	0.11	< .001
Respondent's age	–0.03	0.00	< .001	–0.01	0.00	< .001
Residence						
Rural	Reference			Reference		
Urban	–0.85	0.07	< .001	–0.55	0.04	< .001
Wealth index						
Poorest	Reference			Reference		
Poorer	0.57	0.09	< .001	0.04	0.06	.45
Middle	0.93	0.10	< .001	0.37	0.06	< .001
Richer	1.63	0.11	< .001	0.71	0.07	< .001
Richest	2.93	0.12	< .001	1.58	0.08	< .001
Education						
No education	Reference			Reference		
Primary	0.14	0.09	.103	0.00	0.05	1.0
Secondary	0.97	0.08	< .001	0.44	0.05	< .001
Higher	2.09	0.11	< .001	1.64	0.08	< .001
Caste						
Scheduled tribe	Reference			Reference		
Scheduled caste	–0.35	0.10	.001	–0.97	0.07	< .001
Other backward class	0.77	0.10	< .001	–0.11	0.06	.09
Others[a]	1.40	0.10	< .001	0.30	0.07	< .001
Religion						
Hindu	Reference			Reference		
Muslim	0.35	0.09	< .001	0.28	0.05	< .001
Christian	0.09	0.19	.62	0.07	0.12	.55
Sikh	2.74	0.22	< .001	1.23	0.14	< .001
Buddhist	0.05	0.30	.86	–0.77	0.21	< .001
Jain	1.59	0.51	.002	0.26	0.33	.43
Region						
North	Reference			Reference		
Central	–1.54	0.10	< .001	–2.39	0.06	< .001
East	–2.72	0.10	< .001	–2.14	0.07	< .001
Northeast	–3.40	0.17	< .001	–3.14	0.07	< .001
West	–1.65	0.10	< .001	–3.49	0.11	< .001
South	–1.60	0.10	< .001	–1.88	0.07	< .001
Milk consumption						
Less than once a week	Reference			Reference		
At least once a week	0.65	0.06	< .001	0.40	0.04	< .001
Egg consumption						
Less than once a week	Reference			Reference		
At least once a week	–0.17	0.07	.015	0.12	0.05	.010
Fish consumption						
Less than once a week	Reference			Reference		
At least once a week	–0.04	0.07	.59	0.09	0.05	.076
Meat consumption						
Less than once a week	Reference			Reference		
At least once a week	0.08	0.07	.30	0.05	0.05	.300

a. Other castes represent forward castes.

residents observed in bivariate analyses may be due to other factors, such as greater wealth, more education, and better dietary intake in urban areas. The mean heights of men and women in the richest group were 167 and 154 cm, respectively. These values are still less than the NCHS medians, indicating that even in well-to-do families in India, full growth potential has not yet been achieved. The difference in height between the poorest and the richest is likely to increase, as the secular trend toward increasing height is much greater among the richest than among the poorest, indicating widening socioeconomic disparities. As expected, Sikhs and Jains, who are relatively well off, were the tallest, and Buddhists and Christians were the shortest.

An important finding of this study is the significant positive relationship observed between the percentage of people consuming animal-source foods and the mean height in different states. This relationship was unaltered after adjustment for potential confounders in multiple regression models. Milk intake has long been known to be associated with greater height. Based on epidemiologic studies, Bogin suggested a strong association between milk intake and height [30]. Studies have shown that pastoralists are taller than their counterparts in different parts of Asia [31] and Africa [32]. The secular trend toward increasing height in Japan is thought to be closely associated with increased milk consumption [33]. It is also interesting to note that, despite the consumption of animal-source foods other than milk by a higher proportion of the population in the northeastern states, the mean heights in these states were the lowest in India. The negative association of height with consumption of other animal-source foods in the bivariate analyses may be explained by higher consumption of these foods by the people from the northeast states and their lesser heights. These associations were largely rendered nonsignificant in multiple regression analyses, indicating confounding effects of other variables in the models. It may also be speculated that the role of milk in improving height may be related to factors such as stimulation of insulin-like growth factor 1 (IGF-1), in addition to its protein content. Studies have shown that milk consumption increases IGF-1 levels, which are known to be positively associated with linear growth [34, 35].

The limitations of the study should be acknowledged. Though estimation of secular changes in height based on cross-sectional studies is considered to be a valid method, many studies have adjusted for age-related height loss in participants over 40 years of age [12, 13]. It was not possible to make such correction for age-related height loss in the age group from 40 to 49 years in the present study, since the data needed to estimate the age-related decrease in height are not available for the Indian population. However, the correction of height loss in the age group from 40 to 49 years may further attenuate the estimate of secular increase in height and would not qualitatively alter the finding of an absence of a marked secular increase in height of the Indian population. Moreover, we made a comparative assessment of secular trends in relation to various socioeconomic variables. The age-related decrease in height, if any, is likely to be similar in different groups and would not influence the observed relationships. Another limitation regards the information on dietary intakes. The dietary questionnaire was restricted to a few foods and was qualitative in nature.

Thus, the study provides comprehensive information on height in India in relation to various socioeconomic characteristics, dietary intakes, and associated secular trends, based on a nationally representative sample. It is intriguing to observe that the population in several states is undergoing a negative secular trend in height in a country that has achieved impressive economic growth. We also found a significant relationship between milk consumption and height in different states, which has not received enough attention thus far. The study should stimulate research on the role of milk in improving the linear growth of children. These findings also have important policy implications for countries such as India that have a high prevalence of stunting and a modest secular increase in height.

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