

# Declining Patterns of Average Height of Adult Indians Between 20 and 49 Years: State Wise Trends and Influence of Socioeconomic Factors

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**Abstract** In the present study, changes in the average height over ages among women and men have been studied through third round National Family Health Survey data. It is also aimed to study the extent of influence of the different socioeconomic variables on such changes. The sample sizes for female and male are 94,417 and 52,460, respectively. For this study, only adult male and female data and the age ranges 20–49 years have been considered. During the 30 years span, the data set has been divided into three consecutive time periods with 10 years span for each period like (20–29), (30–39) and (40–49) years. Height has been considered as the dependent variable. The background explanatory variables are type of places, educational attainment, religion, ethnicity, occupational categories and wealth index of the families. The study shows that negative changes occur in the heights over the successive age-groups for men and women separately. The changes are found to be negative in all the zones and most of the states in India though it varies in its intensities. It is also an interesting feature to note that the maximum of absolute growth occurs among the men and women in urban areas, among the richest families, higher educated persons and professionals, while it is not so pronounced among the manual labourers, and scheduled tribes. Is it because of the changing lifestyles of most of the urban families and some of the rural families?

**Keywords** Height • Decadal changes • Socio-economic condition • Regression • India

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## 1 Introduction

There is a considerable variation in trend in adult stature with changes in age and this trend is generally negative with the advancement of age. The negative effect in stature in human body becomes conspicuous in post adulthood phase, i.e., after when one attains around 40 years of age. For some adults it may be visible even in late thirties. There is considerable variation of it among different populations in the world (Harvey 1974; Roche et al. 1981; Malina et al. 1982) and in India (Sidhu et al. 1975; Singh 1978; Bagga 2010, 2013). In India, this type of studies has been carried out for adults who have already attained 60 years and the adults in their twenties (Sharma et al. 1975). It has been found that magnitude of differences between young adults (around 20 years) and late adults (around 70 years) is generally 7–10 cm, though it varies among different communities widely. It may seem to be quite a considerable difference. But Miall et al. (1967) found the decline in stature about 6–7.2 cm among the Welsh women. Among Indian population, very recently, Bagga (2013) studied on Maratha women of 30–70 years and found that it declines up to 3.6 cm.

The decline in the stature with the advancement of age is mainly associated with the changes in the vertebral column, i.e. mainly compression of inter-vertebral discs and hypnosis. This decrement is related with the advancement of age. So, to study the decadal changes, along with the total changes, may reveal features including the intensity of decline in the stature over ages. This change in the length of vertebrae is also associated with osteoporosis and vertebral diseases which cause degenerative changes in vertebral column. Besides this, a few studies in India also stated that socio-economic status has effect on the intensity of degeneration in the stature of human irrespective of gender.

Though there have been studies on the decline in the stature of adults in India, most of the studies, except Bagga's study, dealt with very old data. Even Bagga's study consists of very small sample size and no conclusion can be drawn from such a small sample. In this context, our study provides an opportunity to investigate among adult Indian population through national level data. The objective of the study is to find (1) the decadal changes of the height of women and men of 20–49 years of age and (2) the extent of influence of the different socio-economic variables on such changes.

## 2 Materials and Methods

For this study, we have used the National Family Health Survey (NFHS-III) data conducted by the International Institute for Population Sciences (IIPS), Mumbai, in 2005–2006 (IIPS 2007). IIPS collected unit level data on reproductive aged men of age (15–54) years and women of age (15–49) years from 29 states in India. However, to maintain parity we have taken age range of (15–49) years for both

males and females. The sample sizes thus consist of 94,417 women and 52,460 men in the age-group 20–49 years. It may be noted that each round of NFHS is a cross-section data. The background explanatory variables are (1) type of place—rural and urban areas, (2) educational attainment of women grouped into four categories—illiterate (those who can neither read nor write), primary (literate up to class IV standard), middle (Class V to Class X standard) and high school & above (Class XI and above), (3) religion which is classified into four categories, namely Hindu, Muslim, Christian and Others, (4) ethnicity having four categories such as Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward categories (OBC) and Others, (5) Occupations of the women are clubbed into five major groups like not working; professionals, managers, technicians; engaged in service or sales; engaged in agriculture related works and skilled, unskilled or manual labourers, and (6) wealth index of the families. Wealth index represents the economic status of the households. It is an indicator of the level of the wealth, which is consistent with expenditure and income measure (Rutstein 1999). It is based on 33 household assets and housing characteristics like type of windows, sources of drinking water, types of toilet facility, flooring, roofing, ownership of a mattress, a pressure cooker, a chair, a cot/bed, a table, an electric fan, a radio/transistor, television, telephone, a computer, a car, etc. Each household was assigned a score for each asset and the scores were summed for each household and individuals were ranked according to the score of the household and the scores were divided into five quintile groups starting from lower strata to higher strata like poorest, poorer, medium, richer and richest.

Since the ages of males and females span 30 years, the data set has been divided into three consecutive time periods with 10 years span for each period taking age ranges (20–29), (30–39) and (40–49) years. Height has been considered as the dependent variable. To measure the decadal changes of mean height, the mean height of youngest group (20–29 years) has been subtracted from elder groups (30–39 and 40–49 years) and also the mean height of the middle group (30–39 years) has been subtracted from the mean height of the eldest group (40–49 years), so that the differences between the two consecutive age-groups as well as between the two extreme groups can be compared. Besides correlation between height with age, education and wealth index, we have carried out a regression analysis to see how the socio-economic variables influence the height or rather changes in the height. It was done for each decadal age-group separately for males and females. Thus six regression equations have been found. Here height is the dependent variable and place of residence, education, religion, ethnicity, occupation and wealth index have been considered as independent or explanatory variables. Symbolically we can write

$$y_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + \varepsilon_i. \quad (1)$$

where  $y$  is the dependent variable, i.e., height and the independent variables are  $x_1 =$  Place of residence,  $x_2 =$  Education,  $x_3 =$  Religion,  $x_4 =$  Caste/tribe,  $x_5 =$  Respondent's occupation,  $x_6 =$  Wealth Index and  $x_7 =$  Age in years.  $\alpha$  is the intercept term and the regression coefficients are  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$  and  $\beta_7$ , corresponding to the variables  $x_1, x_2, x_3, x_4, x_5, x_6$  and  $x_7$ .

We have taken binary data for all explanatory variables but age. The binary variables take only 0 for base and 1 for the other category. The base categories are 'Rural' for Place of Residence, 'Primary educated or less' for Education, 'Hindus or Muslims' for Religion, 'SC, ST or OBC' for Castes, 'Other than not working, professionals, technicians or managers' for Occupation and 'Poor or middle income persons' for Economic level. The details of variables, sample sizes, etc. used in the analysis are given in the Appendix. The statistical package for the social sciences (SPSS, version 16.0) has been used for all the analysis.

### 3 Results

Table 1 and Fig. 1a, b give a vivid picture of the mean heights of women of ages (20–29) years, (30–39) years and (40–49) years, along with decadal changes of the mean heights by zones and states in India. The adult decadal growth in height is found to be negative with a reduction of 0.12 cm from 20–29 years to 30–39 years aged women and 0.31 cm from 30–39 years to 40–49 years, the total reduction being 0.43 cm. Small positive changes have occurred only in eight states out of 29 states in India. As many as 21 states witnessed negative changes. The growth is negative in all the zones. The highest total change occurs in South zone (–1.32 cm) and the lowest total change occurs in North zone (–0.10 cm). Out of total eight states in India, where positive changes have been observed, four states, namely Haryana, New Delhi, Punjab and Rajasthan belong to the north zone of India. The other positive growths are seen in Nagaland, Orissa, Uttar Pradesh and Goa. Almost same trend is seen for both the decadal changes. In India, it is also seen that magnitude of reduction in height due to decadal change from 30–39 to 40–49 years is more than 20–29 to 30–39 years. Since there are six zones in India and for each zone two changes are observed, we have altogether 12 changes for the zones. Out of these 12 changes, only 1 case shows positive growth from 20–29 years to 30–39 years in the central zone and the growth is only 0.11 cm.

Table 2 gives almost similar picture for men so far as positive and negative trends in the height, but here positive changes are found to be lesser in number. Also, the amounts of changes are seen to be more than those of women. The total difference is 1 cm, i.e., the change from 20–29 years to 40–49 years is less by 1 cm on the average for all men taken together. When seen zone-wise, the highest difference is –1.79 cm in west zone. The lowest difference is observed in North-east zone. Out of 29 states, the averages in the heights increased for 6 states, namely Arunachal Pradesh, Meghalaya, Jharkhand, Orissa, New Delhi and Punjab, and for the other 23 states the changes are either negative or remain more or less same. The magnitude of difference of this change for men is a bit more than that of women.

Table 3 describes the total difference and decadal changes in the mean height of women in respect of different socio-economic variables. It is seen that total difference is negative in older aged women than in the younger aged women and the magnitude of difference is more or less double in urban areas (–0.59 cm)

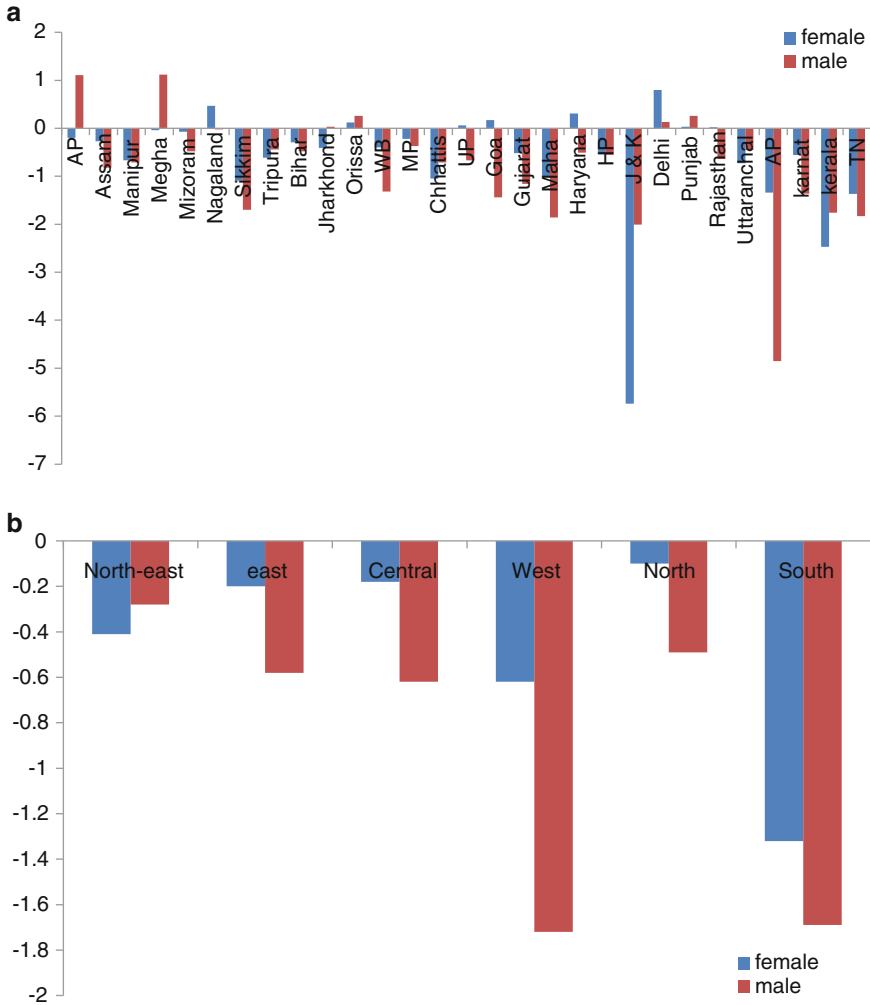
**Table 1** Zone and state wise changes in the mean height of adult women between (20–29) years and (40–49) years in India

Zones/states	Mean height (cm)						Total change (20–29) years and (40–49) years (cm)	Decadal changes	
	(20–29) years (x)		(30–39) years		(40–49) years (y)			(40–49) and (30–39) years (cm)	(30–39) and (20–29) years (cm)
	N	Mean	N	Mean	N	Mean			
<i>North-east</i>	7,730	151.43	5,672	151.35	3,189	151.02	-0.41	-0.33	-0.08
Arunachal Pradesh	582	150.89	423	151.15	190	150.69	-0.20	-0.46	0.26
Assam	1,356	150.61	1,057	150.79	563	150.34	-0.27	-0.45	0.18
Manipur	1,580	152.19	1,227	152.07	726	151.52	-0.67	-0.55	-0.12
Meghalaya	728	149.47	476	149.34	304	149.43	-0.04	0.09	-0.13
Mizoram	654	151.92	499	151.43	287	151.85	-0.07	0.42	-0.49
Nagaland	1,502	152.78	968	152.83	470	153.25	0.47	0.42	0.05
Sikkim	759	151.59	535	151.48	305	150.50	-1.09	-0.98	-0.11
Tripura	569	150.02	487	149.67	344	149.41	-0.61	-0.26	-0.35
<i>East</i>	6,102	150.92	4,671	150.89	3,022	150.72	-0.20	-0.17	-0.03
Bihar	1,286	150.77	884	150.68	593	150.48	-0.29	-0.20	-0.09
Jharkhand	1,014	150.19	736	150.25	396	149.78	-0.41	-0.47	0.06
Orissa	1,559	150.97	1,228	151.09	739	151.09	0.12	0.00	0.12
West Bengal	2,243	151.29	1,823	151.14	1,294	150.89	-0.4	-0.25	-0.15
<i>Central</i>	7,196	151.76	5,618	151.87	3,652	151.58	-0.18	-0.29	0.11
Madhya Pradesh	2,184	152.95	1,689	153.02	1,195	152.73	-0.22	-0.29	0.07
Chhattisgarh	1,257	151.77	1,013	151.55	667	150.72	-1.05	-0.83	-0.22
Uttar Pradesh	3,755	151.07	2,976	151.31	1,790	151.13	0.06	-0.18	0.24

(continued)

Table 1 (continued)

Zones/states	Mean height (cm)						Total change (20–29) years and (40–49) years (cm)		Decadal changes (40–49) and (30–39) years (cm)	
	(20–29) years (x)		(30–39) years		(40–49) years (y)		(y–x)	(40–49) years (cm)	(30–39) and (20–29) years (cm)	
	N	Mean	N	Mean	N	Mean				
<i>West</i>	5, 290	152.41	4, 354	152.17	2, 808	151.79	-0.62	-0.38	-0.24	
Goa	1, 117	152.36	1, 040	152.39	625	152.53	0.17	0.14	0.03	
Gujarat	1, 299	152.70	1, 005	152.68	699	152.18	-0.52	-0.50	-0.02	
Maharashtra	2, 874	152.30	2, 309	151.84	1, 484	151.29	-1.01	-0.55	-0.46	
<i>North</i>	7, 549	154.16	5, 935	154.13	3, 955	154.06	-0.1	-0.07	-0.03	
Haryana	931	154.81	757	155.02	483	155.12	0.31	0.10	0.21	
Himachal Pradesh	1, 059	153.95	924	153.80	569	153.41	-0.54	-0.39	-0.15	
Jammu & Kashmir	1, 072	159.59	776	154.44	520	153.85	-5.74	-0.59	-5.15	
New Delhi	901	153.26	723	153.72	480	154.06	0.8	0.34	0.46	
Punjab	1, 291	154.75	960	154.47	707	154.78	0.03	0.31	-0.28	
Rajasthan	1, 311	154.54	1, 001	154.52	737	154.56	0.02	0.04	-0.02	
Uttaranchal	984	152.88	794	152.83	459	152.15	-0.73	-0.68	-0.05	
<i>South</i>	7, 474	152.95	6, 059	152.38	4, 141	151.63	-1.32	-0.75	-0.57	
Andhra Pradesh	2, 443	152.65	1, 776	152.08	1, 235	151.31	-1.34	-0.77	-0.57	
Karnataka	1, 962	152.69	1, 497	152.73	939	152.13	-0.56	-0.60	0.04	
Kerala	1, 067	154.05	1, 091	152.77	797	151.58	-2.47	-1.19	-1.28	
Tamil Nadu	2, 002	152.99	1, 695	152.16	1, 170	151.62	-1.37	-0.54	-0.83	
<i>India</i>	41, 341	152.31	32, 309	152.19	20, 767	151.88	-0.43	-0.31	-0.12	



**Fig. 1** (a) State wise changes in the mean height of adult female and male between the age-groups (20–29) years and (40–49) years in India. (b) Zone-wise changes in the mean height of adult female and male between the age-groups (20–29) years and (40–49) years in India

than in rural areas (–0.31 cm). In case of relationship with the status of education, illiteracy and primary educated women show positive increments at younger ages and negative growth in older age. The highest educated women have substantially higher heights than other women and do not show much negative trend. Among the Christian and other ethnic groups of women, positive changes are observed, while among Hindus and Muslims, always negative changes occur for all the age-groups. In case of ethnicity, highest negative changes have been found among other backward classes followed by scheduled castes and the lowest differences

**Table 2** Zone and state wise changes in the mean height of adult men between (20–29) years and (40–49) years in India

Zones/states	Mean height (cm)						Total changes (20–29) years and (40–49) years (cm)	Decadal changes	
	(20–29) years		(30–39) years		(40–49) years			(40–49) and (30–39) years (cm)	(30–39) and (20–29) years (cm)
	N	Mean	N	Mean	N	Mean			
<i>North-east</i>	3,966	162.64	3,048	162.59	2,198	162.36	-0.28	-0.23	-0.05
Arunachal Pradesh	228	161.07	163	161.96	125	162.18	1.11	0.22	0.89
Assam	376	163.42	329	163.46	249	162.60	-0.82	-0.86	0.04
Manipur	1,186	163.70	946	163.21	690	162.99	-0.71	-0.22	-0.49
Meghalaya	203	157.87	143	157.84	98	158.99	1.12	1.15	-0.03
Mizoram	226	162.67	159	161.71	120	162.19	-0.48	0.48	-0.96
Nagaland	1,247	163.13	959	163.21	645	163.11	-0.02	-0.10	0.08
Sikkim	291	160.46	181	160.46	122	158.76	-1.7	-1.70	0.00
Tripura	209	161.63	168	161.68	149	161.19	-0.44	-0.49	0.05
<i>East</i>	1,830	163.54	1,593	163.52	1,259	162.96	-0.58	-0.56	-0.02
Bihar	340	163.81	292	163.72	230	163.33	-0.48	-0.39	-0.09
Jharkhand	281	162.81	240	162.98	171	162.84	0.03	-0.14	0.17
Orissa	438	162.98	405	163.06	314	163.24	0.26	0.18	0.08
West Bengal	771	164.00	656	163.91	544	162.68	-1.32	-1.23	-0.09
<i>Central</i>	4,553	165.01	3,594	164.61	2,660	164.39	-0.62	-0.22	-0.40
Madhya Pradesh	861	165.81	674	165.54	536	165.44	-0.37	-0.10	-0.27
Chhattisgarh	385	163.72	386	163.84	266	163.01	-0.71	-0.83	0.12
Uttar Pradesh	3,307	164.96	2,534	164.48	1,858	164.29	-0.67	-0.19	-0.48
<i>West</i>	3,317	166.00	2,710	165.36	1,961	164.28	-1.72	-1.08	-0.64
Goa	312	165.19	318	164.92	219	163.75	-1.44	-1.17	-0.27



Gujarat	415	166.19	359	165.52	294	165.03	-1.16	-0.49	-0.67
Maharashtra	2,590	166.07	2,033	165.40	1,448	164.21	-1.86	-1.19	-0.67
North	2,428	167.08	1,838	166.71	1,377	166.59	-0.49	-0.12	-0.37
Haryana	333	168.38	252	168.40	194	167.87	-0.51	-0.53	0.02
Himachal Pradesh	271	166.09	264	164.96	192	165.54	-0.55	0.58	-1.13
Jammu & Kashmir	319	167.70	244	166.55	143	165.69	-2.01	-0.86	-1.15
New Delhi	371	165.64	189	165.17	155	165.77	0.13	0.60	-0.47
Punjab	421	168.37	288	168.97	248	168.63	0.26	-0.34	0.60
Rajasthan	457	167.29	346	167.38	273	166.65	-0.64	-0.73	0.09
Uttaranchal	256	165.27	255	164.67	172	164.82	-0.45	0.15	-0.60
South	5,747	165.92	4,741	165.11	3,640	164.23	-1.69	-0.88	-0.81
Andhra Pradesh	2,243	166.04	1,664	165.33	1,244	161.19	-4.85	-4.14	-0.71
Karnataka	1,517	165.81	1,320	165.19	958	164.45	-1.36	-0.74	-0.62
Kerala	281	167.55	290	166.15	243	165.79	-1.76	-0.36	-1.40
Tamil Nadu	1,706	165.61	1,467	164.58	1,195	163.78	-1.83	-0.80	-1.03
India	21,841	165.08	17,524	164.63	13,095	164.08	-1.00	-0.55	-0.45

**Table 3** Decadal and total changes in the mean height of women of age (20–49) years in relation to different socio-economic variables

Independent variables	Time period						Total change (20–49) years (cm)	(40–49) and (30–39) years (cm)	(30–39) and (20–29) years (cm)
	(20–29) years		(30–39) years		(40–49) years				
	N	Mean	N	Mean	N	Mean			
<i>Place of residence</i>									
Rural	22,698	152.01	17,655	151.90	11,195	151.70	-0.31	-0.20	-0.11
Urban	18,643	152.68	14,654	152.54	9,572	152.09	-0.59	-0.45	-0.14
<i>Education</i>									
Illiterate	11,275	151.11	13,173	151.48	9,746	151.29	0.18	-0.19	0.37
Primary	5,372	151.24	4,806	151.56	3,564	151.60	0.36	0.04	0.32
Secondary	18,622	152.61	11,082	152.64	5,868	152.49	-0.12	-0.15	0.03
Higher	6,068	154.59	3,246	154.49	1,586	153.85	-0.74	-0.64	-0.10
<i>Religion</i>									
Hindu	29,760	152.20	23,775	152.09	15,551	151.70	-0.50	-0.39	-0.11
Muslim	5,617	152.60	3,906	152.41	2,270	152.15	-0.45	-0.26	-0.19
Christian	3,783	152.11	2,850	152.19	1,737	152.18	0.07	-0.01	0.08
Others	2,181	153.23	1,778	152.99	1,209	153.21	-0.02	0.22	-0.24
<i>Caste\tribe</i>									
SC	6,840	151.21	5,193	151.49	3,290	150.69	-0.52	-0.80	0.28
ST	5,847	151.63	4,172	151.59	2,419	151.47	-0.16	-0.12	-0.04
OBC	12,941	152.22	10,226	152.02	6,370	151.59	-0.63	-0.43	-0.20
Others	13,800	153.18	11,208	152.97	7,735	152.69	-0.49	-0.28	-0.21
DK	208	151.88	199	151.58	143	151.61	-0.27	0.03	-0.30
<i>Occupation</i>									
Not working	25,629	152.44	16,837	152.39	11,045	152.16	-0.28	-0.23	-0.05
Prof/tech/man	1,988	153.93	1,454	154.07	925	153.12	-0.81	-0.95	0.14

Clerk/sales/service	2,642	152.30	3,170	151.79	1,999	151.40	-0.90	-0.39	-0.51
Agriculture	7,204	151.71	7,399	151.79	4,887	151.47	-0.24	-0.32	0.08
Skilled/unskilled lab	3,849	151.75	3,418	151.59	1,888	151.41	-0.34	-0.18	-0.16
<i>Wealth index</i>									
Poorer	4,713	150.67	3,927	150.65	2,083	150.64	-0.03	-0.01	-0.02
Poorest	5,803	150.87	4,684	151.11	2,778	150.70	-0.17	-0.41	0.24
Middle	7,943	151.61	6,094	151.61	3,727	151.28	-0.33	-0.33	0.00
Richer	10,446	152.36	7,646	152.07	4,786	151.66	-0.70	-0.41	-0.29
Richest	12,436	154.02	9,958	153.74	7,393	153.12	-0.90	-0.62	-0.28

observed among scheduled tribes. Occupation-wise the highest total difference is found among service holders (−0.90 cm) and it is followed by professionals (−0.81 cm) while lower magnitudes of differences are observed among non-working women (−0.28 cm) and women engaged in agriculture (−0.24 cm) as well as for skilled/unskilled women labourers (−0.34 cm). The trend is same in both the decades but magnitude is higher in later period than younger ages. Regarding wealth Index, magnitude of negative changes is the highest among the richest women and the lowest among the poorest women.

Table 4 also describes the relationship between decadal changes in stature with different socio-economic variables among Indian men of aged (20–49 years). Secular total change is negative irrespective of all socio-economic variables. High magnitude of total negative changes has been observed in case of urban areas, Hindu religious group, not working and professional occupation holders and richest wealth index families. The same trend is more or less observed in case of decadal changes also.

Table 5 and Fig. 2 show the correlation between adult height with age, wealth index and educational level of men and women. The result shows that height is significantly positively correlated with these three socio-economic variables either negatively or positively. It is also seen that adult height is significantly negatively correlated with the age. Thus it proves that there is a negative trend in the heights with the advancement of adult age.

Table 6 contains the decadal age-group wise results of the linear regression of height with different socio-economic variables separately for female and male data in India. The six fitted regression equations are as follows:

Female height (40–49 years)

$$\hat{y} = 154.6 - 0.668 x_1 + 0.615 x_2 + 0.758 x_3 + 0.983 x_4 - 0.122 x_5 + 1.309 x_6 - 0.088 x_7.$$

(0.000) (0.000) (0.000) (0.000) (0.000) (0.188) (0.000) (0.000)

(2)

Male height (40–49 years)

$$\hat{y} = 165.0 - 0.518 x_1 + 1.155 x_2 - 0.462 x_3 + 1.451 x_4 + 0.329 x_5 + 1.784 x_6 - 0.063 x_7.$$

(0.000) (0.000) (0.000) (0.000) (0.000) (0.072) (0.000) (0.001)

(3)

Female height (30–39 years)

$$\hat{y} = 151.6 - 0.445 x_1 + 0.719 x_2 + 0.178 x_3 + 0.763 x_4 - 0.055 x_5 + 1.441 x_6 - 0.002 x_7.$$

(0.000) (0.000) (0.000) (0.065) (0.000) (0.440) (0.000) (0.096)

(4)

**Table 4** Decadal and total changes in the mean height of men of age (20–49) years in relation to different socio-economic variables

Independent variables	Time period						Total change (20–49) years	Decadal changes	
	(20–29) years		(30–39) years		(40–49) years			(40–49) and (30–39) years (cm)	(30–39) and (20–29) years (cm)
	N	Mean	N	Mean	N	Mean			
<i>Place of residence</i>									
Rural	10,444	164.38	8,899	164.08	6,722	163.60	–0.78	–0.48	–0.30
Urban	11,397	165.71	8,625	165.19	6,373	164.59	–1.12	–0.60	–0.52
<i>Education</i>									
Illiterate	2,378	162.86	3,223	162.92	2,822	162.67	–0.19	–0.25	0.06
Primary	2,940	163.11	2,900	163.42	2,643	163.02	–0.09	–0.40	0.31
Secondary	12,172	165.11	8,373	164.94	5,681	164.51	–0.6	–0.43	–0.17
Higher	3,023	166.76	3,023	166.76	1,944	166.32	–0.44	–0.56	0.00
<i>Religion</i>									
Hindu	15,978	165.19	13,137	164.72	9,866	164.05	–1.14	–0.67	–0.47
Muslim	2,872	165.53	2,026	164.93	1,416	164.70	–0.83	–0.23	–0.60
Christian	1,975	163.24	1,570	163.28	1,187	162.97	–0.27	–0.31	0.04
Others	1,016	165.62	791	165.08	626	165.43	–0.19	0.35	–0.54
<i>Caste\tribe</i>									
SC	3,883	164.10	3,045	163.34	2,070	162.61	–1.49	–0.74	–0.76
ST	2,737	162.69	2,157	162.65	1,558	162.39	–0.3	–0.26	–0.04
OBC	7,892	165.20	6,346	164.77	4,883	164.03	–1.17	–0.74	–0.43
Others	6,625	166.54	5,377	165.99	4,183	165.52	–1.02	–0.47	–0.55
DK	3,883	164.10	3,045	163.34	2,070	162.61	–1.49	–0.73	–0.76

(continued)

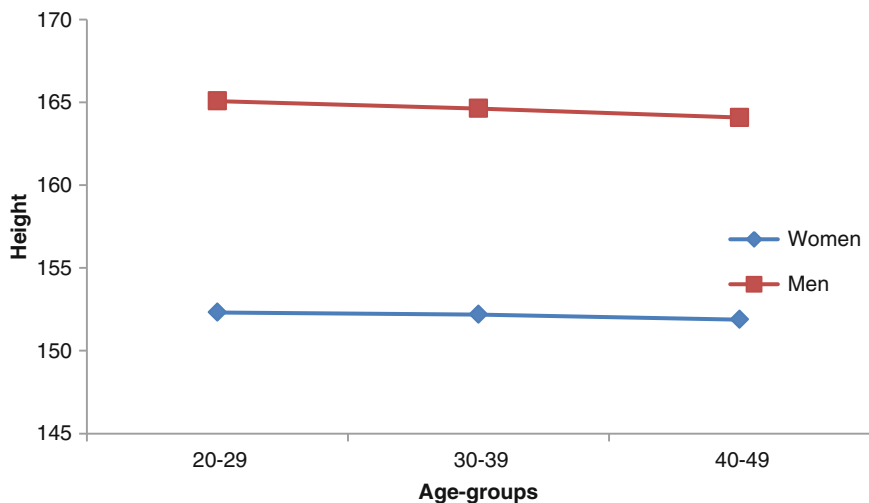
Table 4 (continued)

Independent variables	Time period						Total change (20–49) years	Decadal changes	
	(20–29) years		(30–39) years		(40–49) years			(40–49) and (30–39) years (cm)	(30–39) and (20–29) years (cm)
	N	Mean	N	Mean	N	Mean			
<i>Occupation</i>									
Not working	2,593	166.63	235	164.42	216	164.39	-2.24	-0.03	-2.21
Prof/tech/Man	1,570	166.93	1,695	166.15	1,340	165.38	-1.55	-0.77	-0.78
Clerk/sales/service	5,127	165.51	4,608	165.32	3,400	164.66	-0.85	-0.66	-0.19
Agriculture	4,763	164.27	4,798	163.99	4,062	163.66	-0.61	-0.33	-0.28
Skilled/unskilled lab	7,760	164.39	6,163	164.21	4,054	163.57	-0.82	-0.64	-0.18
<i>Wealth index</i>									
Poorer	1,836	162.46	1,955	162.27	1,391	161.97	-0.49	-0.30	-0.19
Poorest	2,917	163.44	2,533	163.23	1,905	162.48	-0.96	-0.75	-0.21
Middle	4,527	163.88	3,505	163.82	2,540	163.39	-0.49	-0.43	-0.06
Richer	6,107	165.15	4,433	164.77	3,219	164.12	-1.03	-0.65	-0.38
Richest	6,454	167.34	5,098	166.67	4,040	165.97	-1.37	-0.70	-0.67

**Table 5** Correlation between adult heights with age, wealth index and educational level of men and women in India

Height	Variables		
	Highest educational level	Wealth index	Age
Men	0.198** (52,442)	0.223** (52,460)	-0.066** (52,460)
Women	0.158** (94,408)	0.183** (94,417)	-0.030** (94,417)

\*\*The correlation is significant at 0.01 level (figures in parentheses show the number of individuals for which data are available for both the variables of the correlation coefficient)

**Fig. 2** Trend in the mean height of men and women over decadal age-groups

Male height (30–39 years)

$$\hat{y} = 163.7 - 0.239 x_1 + 1.229 x_2 - 0.959 x_3 + 1.302 x_4 + 0.260 x_5 + 1.775 x_6 - 0.031 x_7.$$

(0.000) (0.038) (0.000) (0.000) (0.000) (0.112) (0.000) (0.081)

(5)

Female height (20–29 years)

$$\hat{y} = 150.7 - 0.514 x_1 + 1.099 x_2 + 0.101 x_3 + 0.846 x_4 - 0.065 x_5 + 1.623 x_6 - 0.002 x_7.$$

(0.000) (0.000) (0.000) (0.237) (0.000) (0.330) (0.000) (0.860)

(6)

Male height (20–29 years)

$$\hat{y} = 163.4 - 0.275 x_1 + 1.635 x_2 - 1.230 x_3 + 1.366 x_4 + 0.971 x_5 + 1.984 x_6 - 0.039 x_7.$$

(0.000) (0.011) (0.000) (0.000) (0.000) (0.112) (0.000) (0.021)

(7)

(Figures in parentheses represent level of significance)

**Table 6** Linear regression of height with different socio-economic variables for each decadal group of ages among adult females and males in India

Decadal age-group	Explanatory variables	Dependent variables			
		Female height		Male height	
		Coeff.	Sig*	Coeff.	Sig*
40–49 years	Intercept	154.6	0.000	165.0	0.000
	Place of residence	−0.668	0.000	−0.518	0.000
	Education	0.615	0.000	1.155	0.000
	Religion	0.758	0.000	−0.462	0.006
	Caste/tribe	0.983	0.000	1.451	0.000
	Respondent's occupation	−0.122	0.188	0.329	0.072
	Wealth Index	1.309	0.000	1.784	0.000
	Age	−0.088	0.000	−0.063	0.001
30–39 years	Intercept	151.6	0.000	163.7	0.000
	Place of residence	−0.445	0.000	−0.239	0.038
	Education	0.719	0.000	1.229	0.000
	Religion	0.178	0.065	−0.959	0.000
	Caste/tribe	0.763	0.000	1.302	0.000
	Respondent's occupation	−0.055	0.440	0.260	0.112
	Wealth index	1.441	0.000	1.775	0.000
	Age	−0.019	.096	−0.031	0.081
20–29 years	Intercept	150.7	0.000	163.4	0.000
	Place of residence	−0.514	0.000	−0.275	0.011
	Education	1.099	0.000	1.635	0.000
	Religion	0.101	0.237	−1.230	0.000
	Caste/tribe	0.846	0.000	1.366	0.000
	Respondent's occupation	0.065	0.330	0.971	0.000
	Wealth index	1.623	0.000	1.984	0.000
	Age	−0.002	0.860	−0.039	0.021

\*The p-values are shown in this column

The results of the linear regressions can easily be understood if the values of the regressors are known. When we look at the regression results we see that some relations give different or opposite results than those obtained from taking the simple group means. The place of residence is consistently negatively related with height in the regression equation and the coefficient is significant in all the cases. Observe that we have taken the value 1 for urban and 0 for rural and the negative coefficient of place of residence clearly indicates that rural adults have more height if the effect of other variables is eliminated. The mean values of height in the rural and urban cases give the opposite results. The mean height of urban adults is always more than the mean height of rural adults for each combination of age-group and gender. Other regression coefficients, except religion, more or less give expected results. Age is seen to have a negative relation with height both for the regressions and for group averages. Wealthier or more educated persons have higher heights on the



average. Caste is also positively related with height. This means that General Caste Hindus, Christians, etc. have higher heights than SC, ST and OBC people. However, occupation is not significantly related with height for most cases. Religion needs special mention here, because it is positively related with height for females, but negatively related with height for males. This result conforms to the result of the corresponding group means.

## 4 Discussion

The paper investigates the changes in height vis-à-vis changes in age-groups of adult men and women in India taking three age-groups, namely (20–29), (30–39) and (40–49) years. The reduction in the average height is 0.12 cm from 20–29 years to 30–39 years aged women and 0.31 cm from 30–39 years to 40–49 years, the total reduction being 0.43 cm. So the study shows negative changes in the heights over the successive age-groups. The decadal changes are found to be negative in all the zones of India though it varies zone-wise greatly. Among the women, south zone shows the highest (1.32 cm) and north zone shows the lowest (0.10 cm) change. In most of the states, negative growth occurs but in a few states, positive growth occurs for both the gender groups. In case of men, the highest (1.79 cm) and the lowest (0.28 cm) changes are observed in west and north-east zones, respectively. When male and female heights are compared, the magnitude in the total change is found to be more in males more than in females. The changes in the heights have also been seen among the different socio-economic groups. It is seen in almost all cases that negative changes occur regardless whether it is found for men and women separately or found for all adults in India. It is also an interesting feature that in urban areas, among the richest and richer families, maximum negative increments occur, while among the manual labourers, and scheduled tribes, low magnitude of negative increment occurs. But it is firmly confirmed that height reduces with the advancement of age. Thus it propagates the idea that in human body, post adulthood changes do occur in height. It is supported by many findings (Miall et al. 1967; Roche et al. 1981; Malina et al. 1982; Kirchengast 1994). The most supporting relevant work staking Indian data are (Bagga 1998, 2013; Bagga and Sakurkar 2013). This type of study was mainly done in India or around the world during 1980s and 1990s and in that period, the difference was 5–7 cm (approximately) from younger to older generation, but in our study, the difference is found to be only 0.43 cm. It may be due to the fact that we have taken a smaller span of total years (20–49 years) compared to the time span (20–70 years) taken by them. But, even then, the change in height found by us is too less compared to the changes found by them. It is true that the degeneration starts after 40 years (Roche et al. 1981; Noppa et al. 1980; Sussame 1977; Cline et al. 1989). To understand the changes in the height over age, the span of age must be from 30 to 70 or 80 years. But here, the terminal point of age is 49 years only. As the data is from secondary sources, the male data is available up to 54 years and female data is available up to 49 years. So

we have taken all data from 20 years to 49 years to maintain the parity between male and female data. It needs further investigations to see when the degeneration starts and how much degeneration occurs. The effect of the socio-economic variables also needs to be further explored. Is it true that more changing lifestyle in a broad sense which includes changing food habits also result into more degeneration of height? We have in fact seen that more negative changes occur among the urban people, and richer and richest families as age increases.

## Appendix

**Data Type** Unit level data as obtained from the third National Family Health Survey (NFHS – III) conducted by the International Institute for Population Sciences (IIPS), Mumbai, in 2005–2006.

**Sample Size** The sample sizes consist of 94,417 women and 52,460 men in the age-group 20–49 years. IIPS collected unit level data on reproductive aged men of age (15–54) years and women of age (15–49) years from 29 states in India. However, to maintain parity we have taken age range of (15–49) years for both males and females

Time span for total and consecutive period for Decadal changes: 20–49 years with three consecutive time span like (20–29), (30–39) and (40–49) years.

**The Variables Considered in the Paper** All the variables, except height, are grouped into categories. (For regression analysis the variables are treated in a different manner.)

**Height:** The height is measured in centimetres.

**Age:** (1) 20–29 years, (2) 30–39 years and (3) 40–49 years.

**Place of residence:** (1) Rural and (2) Urban areas.

**Educational level:** (1) Illiterate (those who can neither read nor write), (2) Primary level (literate up to class IV standard), (3) Middle level (Class V to class X standard) and (iv) High school & above (class XI and above).

**Religion:** (1) Hindu (2) Muslim (3) Christian and (4) Others,

**Ethnicity:** (1) Scheduled Castes (SC) (2) Scheduled Tribes (ST), (3) Other Backward Categories (OBC) and (4) Others.

**Occupations:** (1) Not working; (2) Professionals, managers and technicians, (3) Service or sales (4) Agriculture related works and (5) Skilled, unskilled or manual labourers, and

**Wealth index of the families:** (1) Poorest (2) poorer (3) Middle (4) Higher and (5) Highest. The details of how wealth index is classified into these categories are given in the main text.

### The Variables Taken in the Linear Regression Analysis

The dependent variable is Height. All the independent variables, except age, are taken as binary variables where '0' is the base category and the rest of the categories are grouped and given the value '1'. Age is taken in years. We shall mention only the base categories below:

**Place of residence:** Rural;

**Educational level:** Primary level or less, i.e., Illiterate or literate up to class IV standard;

**Religion:** Hindu or Muslim;

**Ethnicity:** SC, ST or OBC;

**Occupations:** 'Service or sales', 'Agriculture related works or Skilled', 'Unskilled or manual laborers', i.e., Other than not working, professionals, technicians or managers; and

**Wealth index of the families:** Poorest, poorer or Middle income persons.

**Age:** Age is taken in years. It should be mentioned here that the regression analyses were performed separately for each group of (1) 20–29 years, (2) 30–39 years and (3) 40–49 years. Thus for the group 20–29 years, say, the age as an explanatory variable takes values from 20 to 29 years.

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