Human Stature and Development with special reference to Indian population

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Abstract: Background: Variation in human height around the globe as well as within a specific region or population is considered as reflection of health, wellbeing and long and short term adaptations. Human height is determined by a combination of genetic and environmental factors particularly diet and healthcare plays a significant role. Undernutrition during early childhood leads to stunting and poverty is one of the important causes of undernutrition. Still, it was reported that human height has steadily increased over the past two centuries across the globe. This trend is in line with general improvements in health and nutrition during this period. Historical data on heights tends to come from soldiers (conscripts), convicted criminals, slaves and servants. It is for this reason much of the historical data focuses on men. Recent data on heights uses additional sources including surveys and medical records. Here, the primary objective is to understand the variation of height around the globe with special reference to Indian population and to assess the relationship with human development index (HDI) and stature.

Material and Methods: For present investigation three dataset on stature were analyzed from three different databases. Primarily, the investigation is based on anthropometric data collected on adult males of 18+ years of age belonging to 118 caste/tribe/ethnic/religious groups residing in 161 districts of 14 states of Indian Union. The data was collected by the trained physical anthropologists of Anthropological Survey of India, following standard techniques using standard instruments. Measurements were taken on adult apparently healthy males. Efforts were also made to exclude closely related individuals. Verbal informed consent was obtained from the study participants and they were illustrated in detail about the study objectives. A total of 43952 adult males were measured for height. The representative samples were drawn from each of the district of the states. To achieve the goal of representative sample, data was collected from different caste/tribe/religious group residing in every particular district and state. These states covered for present investigation are homeland of 759 million populations, which is 62.7% of the total population of India.

The second database is based on two consecutive anthropometric surveys conducted in Sagar district of Madhya Pradesh (Central India). The first survey was part of Anthropometric survey conducted by Anthropological survey during 1970s. The second one was conducted during 2006 which was limited to 5 ethnic/caste/religious groups.
To understand the global variation and predictors of human stature, country-wise average heights were obtained from across the globe. To understand the secular trend and predictors of human stature the data on country-wise average stature around the globe was collected. Simultaneously,

data on Human Development Index (HDI) were obtained to understand the impact of development on adult Human Stature.

Results: There is wide variation in stature of adult male and females around the globe on the basis of ethnic origin, geographical location, climate and socio-economic conditions. On the basis of Indian data, it was found that ethnic and regional variation in adult human stature is predominated by their ethnic origin.The tribes (ST) have shortest stature (161.45±5.95 cm) followed by scheduled castes (SC), other backward castes (OBC), Jain, Muslims and General Castes (GC). The Sikhs are tallest in India with an average height of 169.09±6.59 cm. Besides caste and occupation, nutritional status was also found to be determinants of adult stature. Significant regional variation in stature was observed in India with Meghalaya males being shortest and Haryana and Punjab males being tallest in this dataset. The regression analysis was computed to find out the role of development in determining the stature around the globe.

Conclusion: Variation of human height is modulated by both genetic makeup and environment predictors. Adult stature is an outcome of nutrition and health care available during infancy, childhood and adolescence. Income, occupation, caste (Indian), ethnicity, climate, geo-political environment and development etc. are main determinants of human stature. In Indian context Pan-Hindu caste stratification is one of the predominant determinants of stature.

Keywords: Height, caste, human development index, ethnicity, global variation.

Introduction

Adult human stature or height is an outcome of long-term and short-term adaptations. Genetic structure, nutrition, economy, occupation, political scenario, socio-economic and geo-climatic milieu etc. can influence your stature. Poverty leads to poor nutrition and ultimately results into stunting. For full expression of genes good nutrition as well as better and conducive environment is needed. Sequencing of human genome has identified 697 genetic variants that influence the height of an individual (Wood et al. 2014). According to Henneberg (2001) long-term body size and shape are a manifestation of natural selection and genetic effects, thus variability in individual stature is primarily governed by genetic material. Therefore, it is a heritable character (Cavalli-Sforza &Bodmer 1971, Susanne 1971, Mueller 1976, Roberts *et al*. 1978, Wood et al. 2014). According to Birdsell (1993) many environmental influences can alter final stature; including the effects of nutrition, disease and social status. According to Scheuer and Black (2000) these factors have predominant influence during infancy and childhood and may reflect a broad socioeconomic picture of society.

According to Deaton (2007) height is an indicator of health. Tanner (1987) has rightly pointed out that the growth study of a population is a mirror that reflects conditions in society; hence, there has been intense research interest in the area of linear growth in developing countries, including India (Mamidi et al. 2011). Taller individuals earn more, either because they are physically more capable of work (Strauss and Thomas, 1998) or because height is an indicator of higher cognitive potential in the sense that people who do not reach their full genetic height potential probably do not reach their full cognitive potential either (Case and Paxon, 2006). Further, according to Waaler (1984) on average, taller people live longer. According to Deaton (2007) the relationship between adult human height and economic growth is reciprocal-better economic growth permitting physiological growth, through better nutrition; and depending on it, through the enhanced ability of taller and stronger people to work.

According to Elo and Preston (1992), Finch and Crimmins (2004) and Crimmins and Finch (2006) the height-restricting biological responses to childhood nutritional insults and disease may have a short-run survival advantage but negative consequences in later life. In consequence, shorter people are more prone to chronic disease in late life and likely to die earlier (Deaton, 2007). The cognitive disadvantages of these insults will restrict educational opportunities, and both education and cognitive ability are well documented predictors of better health (Deaton, 2007). The restriction of height by malnutrition and disease may no longer be important in rich countries, but the process is certainly far from complete in poor countries, where infant and child mortality rates remain high, and average nutritional intake is low (Deaton, 2007).

India being a land of vast human diversity consists of 4635 anthropologically well-defined populations(Singh et al. 1994). Archaeological evidence suggests that human habitation in Indian subcontinent began from Early Stone Age dating 250,000 YBP. People from different ethnic stocks, cultures and languages started migrating to India from different directions and contributed significantly to the present day gene pool. Also, the varied ecological regime of

the country nurtured this diversity and bears testament to human's adaptability to an array of environmental conditions. Further, the country is characterized by subdivided population structure. The practice of endogamy among castes and tribes keeps them in isolation by point of view of gene flow. Bharati et al. (2005) rightly pointed out "geographical clines or patterns are expected among some large castes, sub-castes and tribes residing in contiguous geographical regions over larger areas as per the isolation by distance model of population structure. Thus biological diversity of Indian populations is influenced by geography, social, ethnic and linguistic affiliation; however, the patterns vary with respect to the type of populations and its characteristics" and resulted into wide biological variation including variation of stature.

There has been strong research interest in the area of linear growth in developing countries, including India (Mamidi et al. 2011), however, adult stature has 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 (Shatrugna and Visweswara, 1987 and Visweswara et al. 1993), but the average height of the population and associated secular trends in height based on a nationally representative sample have not been reported (Mamidi et al. 2011). Therefore, the primary objective of this study is to understand the dynamic of stature among different sections of Indian population; to find out regional variation of stature; to explore the secular trend of stature, to compare Indian data with internationally available data and discover the predictors of stature among Indian population and in general.

Materials and Methods

For present investigation three dataset on stature were analyzed from three different databases. To understand the secular trend of stature among Indian population in the year 2006, five caste/ethnic groups were selected viz. Gond (ST), Chamar (SC), Lodhi (OBC), Brahmin (GC) and Muslim from Sagar district of Madhya Pradesh (Ahmed 2007). A total of 258 individuals were measured for stature and other anthropometrics following the standard protocol maintained during the first survey conducted by Anthropological survey of India during 1970s.

The primary database was generated by digitization of publications of anthropometric survey, in which, series of volume on individual anthropometric data was published by (Basu et al. 1994) conducting cross sectional nationwide survey and anthropometric data were collected on adult males of 18-84 years of age. Data on stature of a total of 43952 adult males were analyzed for present investigation. They belong to 118 caste/tribe/ethnic/religious groups residing in 161 districts of 14 different states. The survey has wide coverage and representative samples were drawn from different districts and states.

Here, it should be noticed that states covered for anthropometric survey by anthropological survey of India during 1970s are now homeland of 759 million populations, which is 62.7% of the total population of India. The average sex ratio of these states was 933 female per thousand of males. The population density in the area covered was 405 persons per square kilometer. The average decadal growth rate of the region was 20% during 2001-2011 (Census of India, 2011). According to Sample Registration Survey (SRS, 2014) the average crude birth rate (CBR), death rate (CDR) and infant mortality rate (IMR) of the area covered was 21.4, 7.0 and 40.0 respectively.

The third database analyzed is year wise country wise average stature for 151 countries. This data base has information on average stature for countries from year 1810 to 1980 at an interval of 10 years. Out of 151 countries, only data of those countries were analyzed, which are represented completely either vertically or horizontally, as data for some of countries for some of years were missing. The fourth database was created for the analysis of correlation and regression based on nation wise stature and human development index (HDI).

Data collection

The data on Indian population was collected following standard techniques (Martin and Saller 1956). Measurements were taken on adult males who looked apparently healthy. Efforts were also made to exclude closely related individuals, such as brothers and fathers and sons, and individuals with any kind of physical deformities. Before collection of the data, the instruments were standardized. Verbal informed consent was obtained from the study participants after they were provided with the study objectives.

Data Management

The individual data on age, caste, ethnic group, state and stature were segregated from main database and cleaned for any errors.

Statistical Analysis

MS Excel and SPSS (statistical package for social sciences) softwares were used for statistical analysis viz. central tendencies, t-test, F-test, ANOVA test and Regression analysis.

Results

It is evident from Table 1 that almost half (47.6%) of adult male populations of India are of medium stature (163-172.9 cm); whereas 42.4% are short (152.1-162.9 cm). A total of 3.1% are very short (<152 cm) and 6.9% are Tall (173-203 cm).A total of 79% population falls under the stature of 157 to 172 cms (Figure 1). Further to display the distribution of population and stature category a box plot diagram is plotted (Figure 2) which exhibit mean stature for category as well as quartiles and extreme values.

To understand, how the dynamics of social structure and caste hierarchy have impacted human stature. Category wise distribution of Ethnic group is displayed in Table 2 and Bar diagram (Figure 3). It is apparent that high proportion of socio-economically deprived section of Indian population viz. Scheduled Tribes (ST), Scheduled Castes (SC), Other backward castes and Muslims have very short and short stature. At the same time none of the Sikh were found in the category of very short stature (<152 cm). On the other hand the medium type of stature is dominated by Sikh (53.8%), General Castes (53.6%) and Muslims (51.8%); whereas Tall stature is dominated by Sikh (30.2%) and General Caste (10.2%) people. The study reveals that there is significant difference in stature as per their socio-economic status and hierarchy in caste structure (Figure 4).

State wise distribution of sample as per stature category is displayed in Table 3. It can be observed that the state of Meghalaya has highest proportion of very short (20.4%) and short (63.3%) statured individuals followed by states like Orissa, Chhattisgarh and Bihar. People of Haryana and Punjab are comparatively taller than rest of the states. For further elucidation error bar diagram plotted, which clearly shows that the people of Meghalaya are significantly short in stature as compared to rest of the states and people of Haryana and Punjab are significantly taller (Figure 5).

Table 1. Distribution of Indian population as per stature category (1970s)

Stature category	N	%
Very Short (<152 cm)	1361	3.1
Short (152.1-162.9 cm)	18633	42.4
Medium (163-172.9 cm)	20941	47.6
Tall (173-203 cm)	3017	6.9
Total	43952	100

Table 2. Ethnic group mean and standard deviation as well as stature category wise distribution of the Indian Population(1970s)

Ethnic Group	Mean Stature±SD	Stature Category									
		Very Short (<152 cm)		Short (153-162.9 cm)		Medium (163-172.9 cm)		Tall (173-203 cm)		Total	
		N	%	N	%	N	%	N	%	N	%
Tribe (ST)	161.5±5.9	303	5.4	3062	54.7	2102	37.5	135	2.4	5602	100
Schedule Castes (SC)	162.6±5.9	269	3.6	3684	48.7	3294	43.5	317	4.2	7564	100
Backward Castes (OBC)	163.3±6.2	357	3.4	4704	44.8	4812	45.8	631	6	10504	100
General Caste (GC)	165.1±6.3	302	2.1	4828	34.1	7573	53.6	1437	10.2	14140	100
Jain	163.7±6.0	14	1.8	347	43.5	390	48.9	47	5.9	798	100
Muslim	164.3±6.1	116	2.3	1976	38.4	2663	51.8	390	7.6	5145	100
Sikh	169.1±6.6	0		32	16.1	107	53.8	60	30.2	199	100
Total	163.7±6.3	1361	3.1	18633	42.4	20941	47.6	3017	6.9	43952	100

Table 3. State wise and stature category wise distribution of the Indian Population(1970s)

	Stature Category									
	Very Short (<152 cm)		Short (152.1-162.9 cm)		Medium (163-172.9 cm)		Tall (173-203 cm)		Total	
States	N	%	N	%	N	%	N	%	N	%
Assam	78	4.4	908	50.8	746	41.7	56	3.1	1788	100
Bihar	186	5.1	1847	51.0	1415	39.0	176	4.9	3624	100
Chhattisgarh	82	5.4	758	49.9	624	41.1	54	3.6	1518	100
Gujarat	116	3.1	1674	44.2	1788	47.2	210	5.5	3788	100
Haryana	4	0.5	153	19.2	472	59.3	167	21.0	796	100
Jammu and Kashmir	17	2.1	315	39.5	424	53.1	42	5.3	798	100
Jharkhand	53	4.4	623	52.2	487	40.8	30	2.5	1193	100
Madhya Pradesh	223	2.2	3982	39.9	5075	50.9	695	7.0	9975	100
Maharashtra	220	3.2	3150	45.9	3134	45.7	352	5.1	6856	100
Meghalaya	10	20.4	31	63.3	8	16.3	0		49	100
Orissa	234	5.5	2236	52.5	1614	37.9	175	4.1	4259	100
Punjab	8	0.5	343	22.2	890	57.5	306	19.8	1547	100
Uttar Pradesh	103	1.6	2118	33.4	3502	55.2	624	9.8	6347	100
Uttarakhand	27	1.9	495	35.0	762	53.9	130	9.2	1414	100
Total	1361	3.1	18633	42.4	20941	47.6	3017	6.9	43952	100

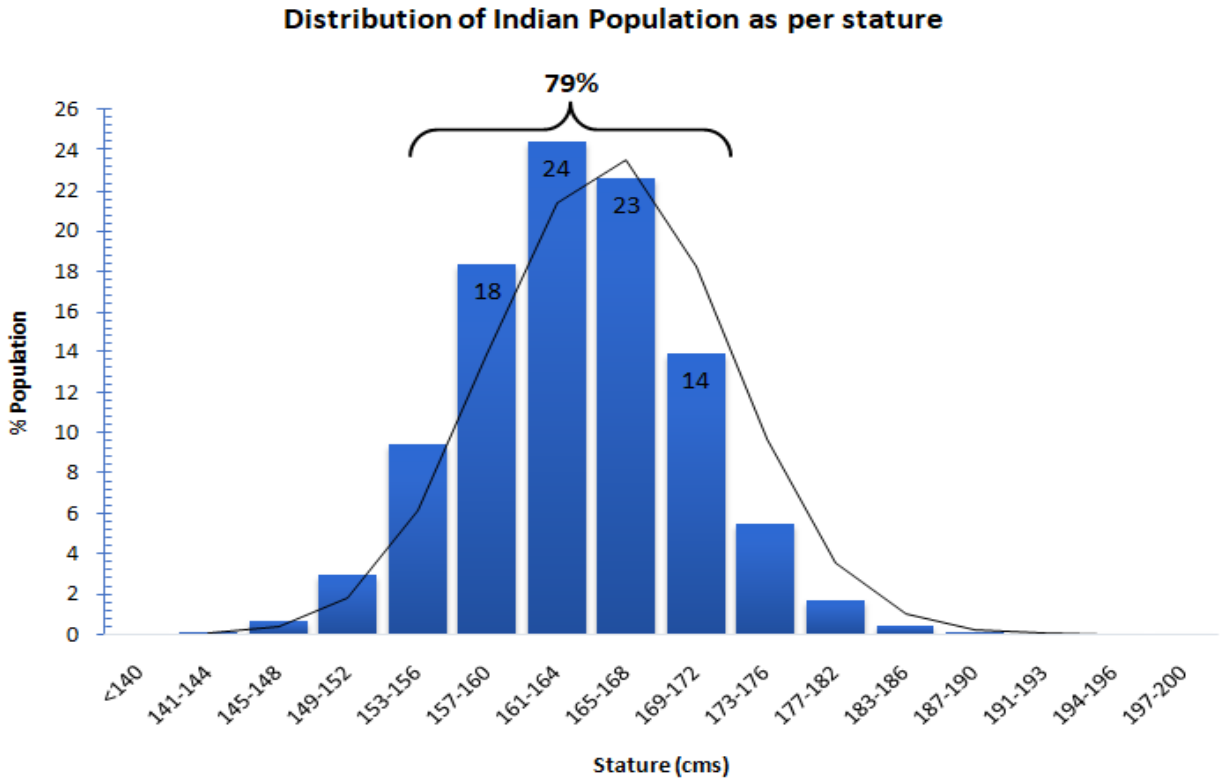


Figure 1. Distribution of Indian population as per stature.

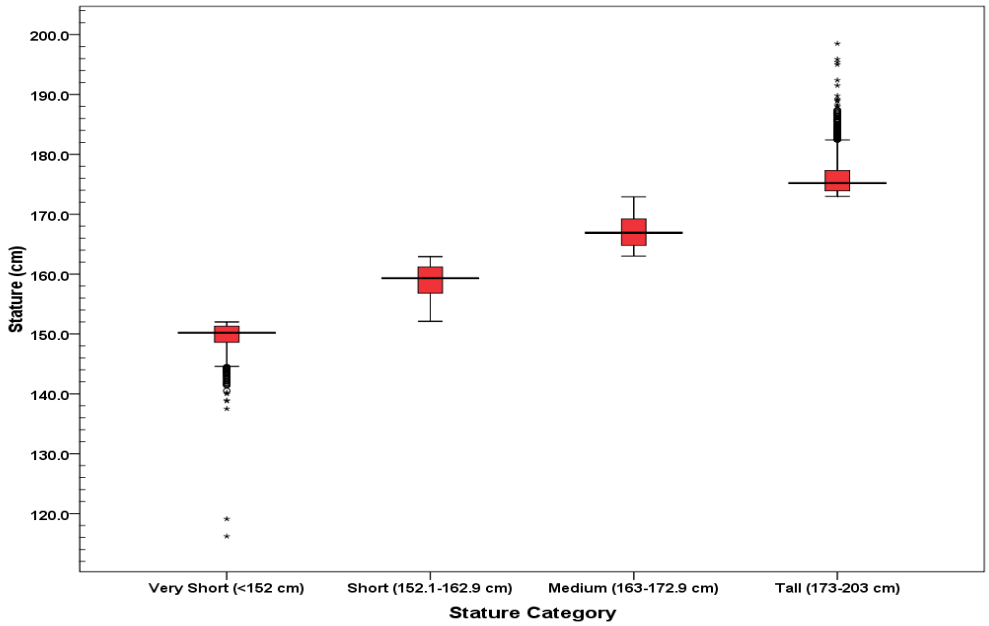


Figure 2. Box plot diagram showing stature category wise mean and quartiles.

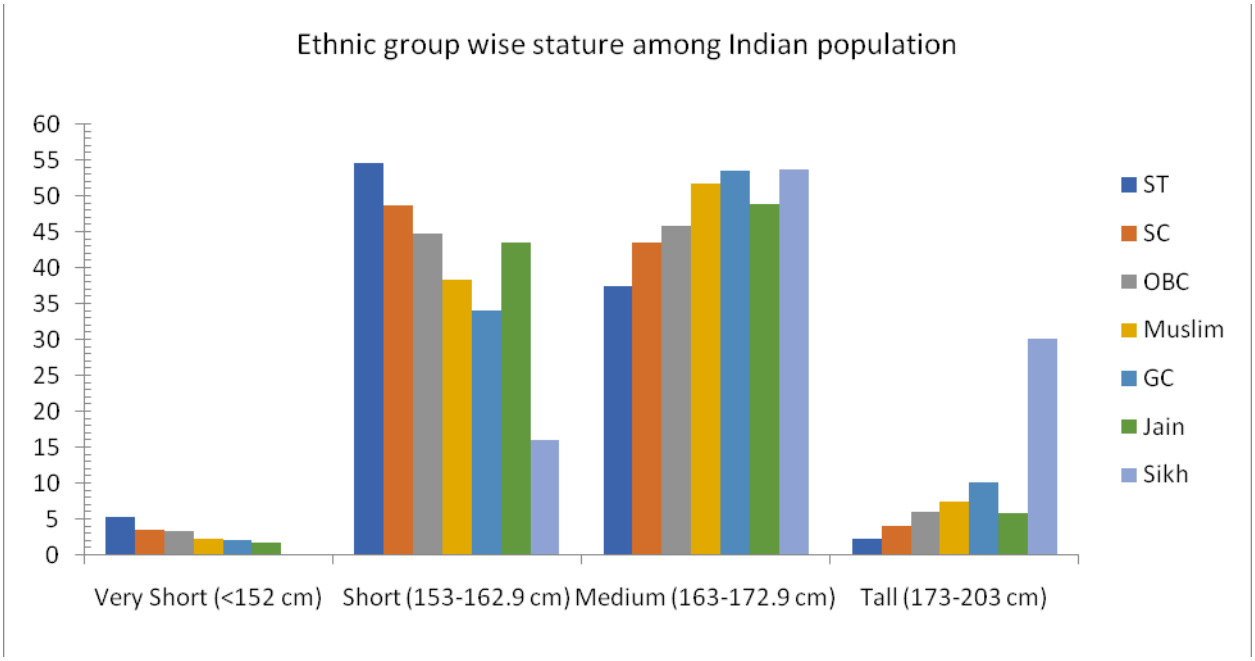


Figure 3. Ethnic group wise stature among Indian Population

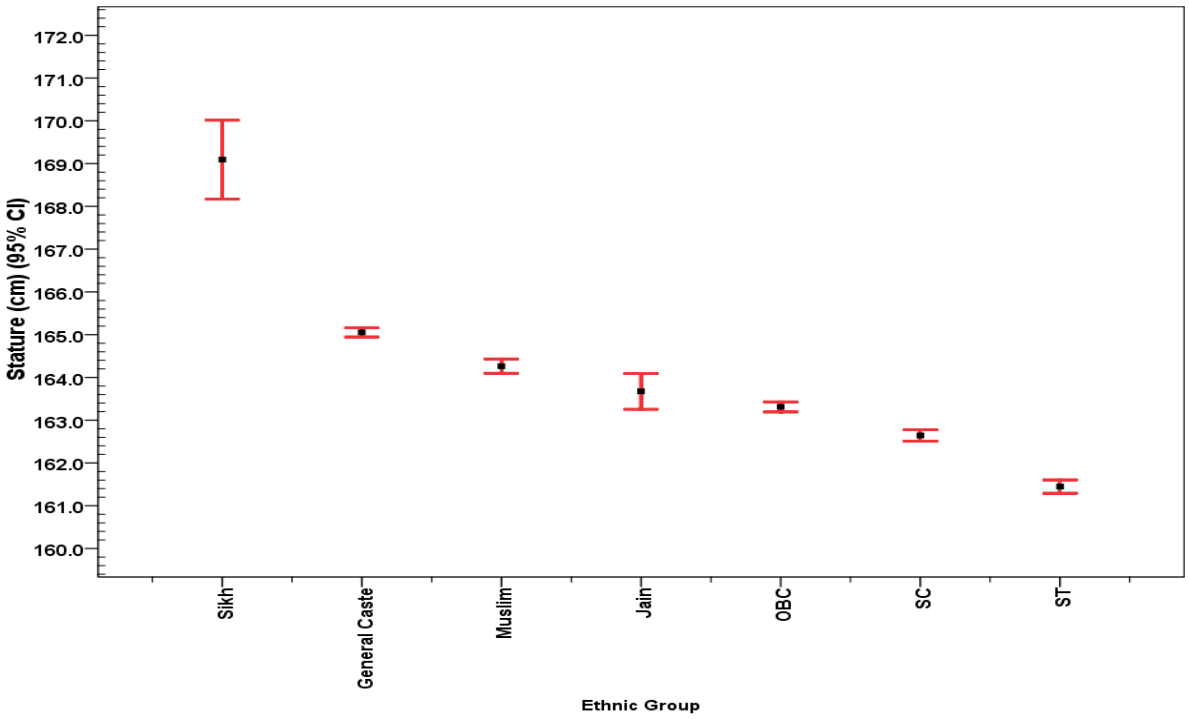


Figure 4. Error bar diagram showing extent of difference in stature among different ethnic groups.

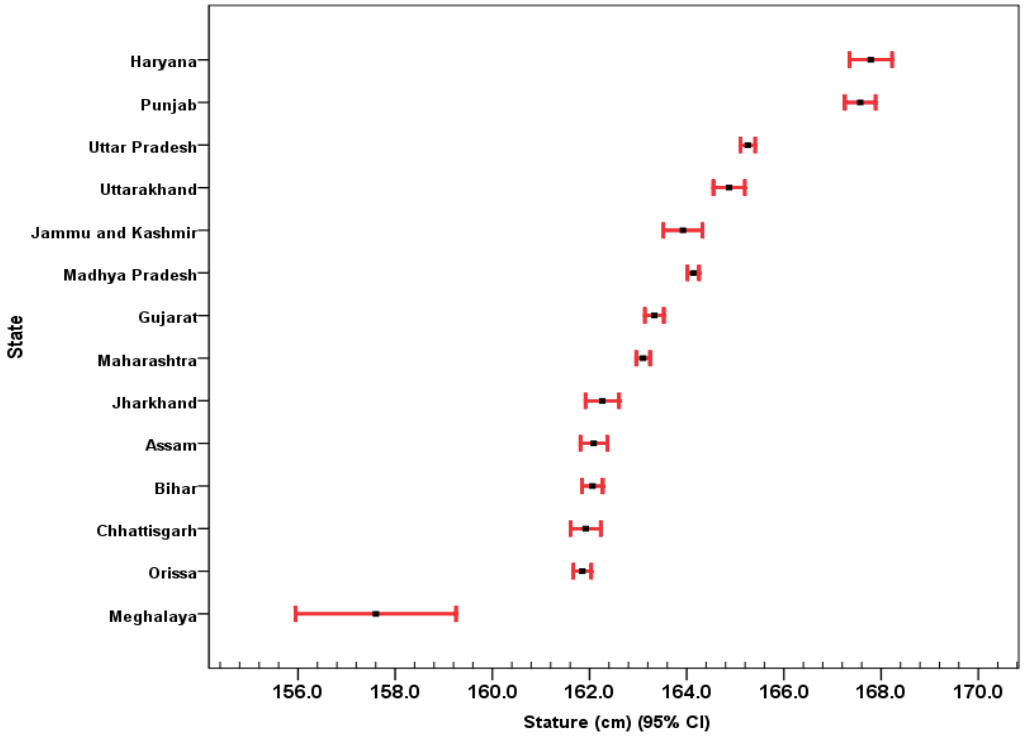


Figure 5. Error bar diagram showing extent of difference in stature among residents of different states.

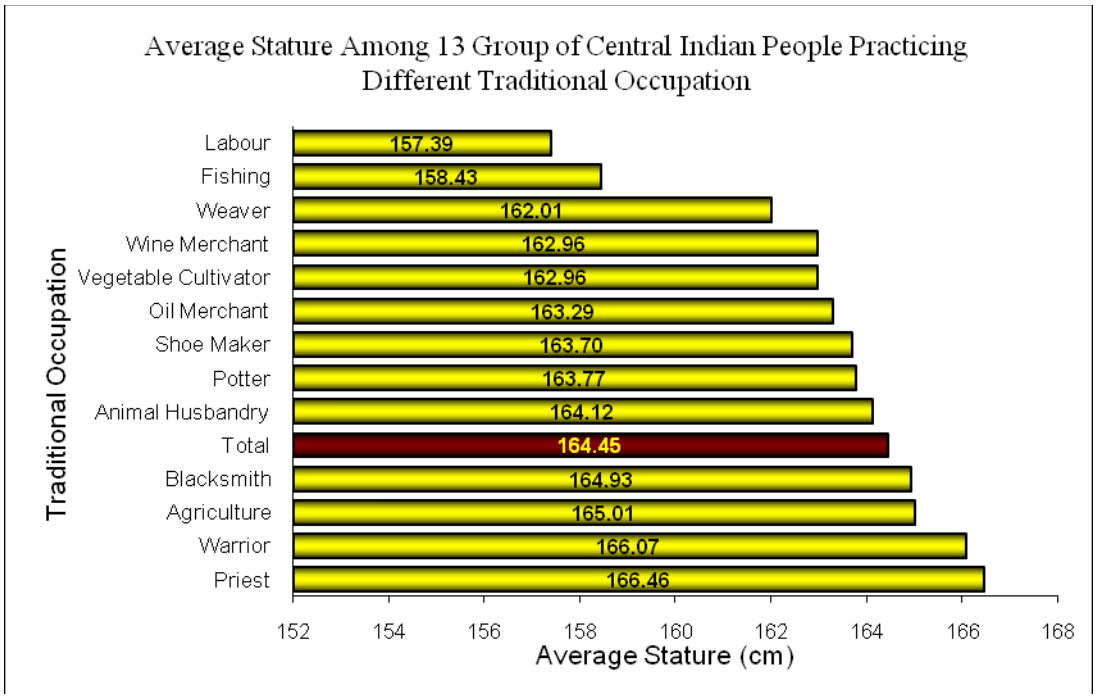


Figure 6. Average Stature among 13 group of central Indian people practicing different traditional occupation

Table 4 displaying state wise comparative mean and standard deviation of stature in a gap of 35 years as well as mean of increment in stature of the population. It is evident from the Table that all the states have positive increment in mean stature except the states of Meghalaya (-0.3 cm), Uttar Pradesh (-0.88 cm) and Uttrakhand (-0.25 cm).Mamidi et al.(2011) also reported lowest increment of height among the men of the state of Meghalaya, where a negative secular trend at a rate of –0.73 cm per decade was found($p < .05$).As per present investigation, the states attain highest increments are Jammu and Kashmir (2.85 cm) followed by Maharshtra (2.08 cm), Gujarat (2.06 cm), Bihar (1.53 cm), Chhattisgarh (1.53 cm), Madhya Pradesh (1.22 cm), Orissa (1.1 cm), Assam (0.99 cm), Punjab (0.73 cm), Jharkhand (0.53 cm) and Haryana (0.18 cm).

Further to understand the micro level differencesof stature between caste/tribal groups.Population/ethnic group wise mean stature along with standard deviation (SD) and 10^{th}, 50^{th} and 97^{th} percentile of stature is computed and presented in Table 5. To understand the extent of variation between 118 castes/tribes One Way ANOVA was computed, the value of F was found 44.5 and significant ($p<0.001$). Similarly the F value for 14 states was found quite high ($F=197.5$, $p<0.001$), further it is higher for ethnic groups viz. Scheduled tribe, Scheduled castes, Other backward castes, General Castes, Jain, Muslim and Sikh ($F=312.6$, $p<0.001$).

To understand the role of occupation on stature, here data of 22 castes group practicing 13 different traditional occupations were segregated and analyzed. The findings are plotted as occupation wise mean stature in a bar-diagram (Figure 6). It is evident that the caste group engaged in priesthood was tallest one with 166.46 cm of mean stature followed by warrior (166.07 cm), agriculturist (165.01 cm), blacksmith (164.93 cm), pastoralists (164.12 cm), potter (163.77 cm), shoe maker (163.70 cm), oil merchant (163.29 cm), vegetable cultivator (162.96), wine merchant (162.96), weaver (162.01), fisherman (158.43 cm) and labour (157.93 cm) for further details Gautam (2007 and 2008) can be referred.

To assess the secular trend of stature among adult Indian males another database is needed from the same population and same region at definite interval. Therefore, in year 2006, samples were drawn from five populations viz. Gond (ST), Chamar (SC), Lodhi (OBC), Brahmin (GC) and Muslim. It was found that mean stature has increased among all deprived sections viz. ST, SC, OBC and Muslims, whereas the difference of stature among Brahmin was found negative. The findings are plotted as bar diagram (Figure 7).

Table 4. State wise mean and standard deviation of stature during 1970s and 2006 and mean increment in 35 years.

S.No.	States	Stature (cm)				
		1970s		2005-06		Mean Increment (cms)
		Mean	SD	Mean	SD	
1	Assam	162.1	6.0	163.1	6.91	0.99
2	Bihar	162.1	6.5	163.6	6.79	1.53
3	Chhattisgarh	161.9	6.2	163.4	6.48	1.53
4	Gujarat	163.3	6.1	165.4	6.93	2.06
5	Haryana	167.8	6.3	168.0	6.60	0.18
6	Jammu and Kashmir	163.9	5.8	166.8	7.60	2.85
7	Jharkhand	162.3	6.1	162.8	6.62	0.53
8	Madhya Pradesh	164.1	6.1	165.3	6.76	1.22
9	Maharashtra	163.1	6.0	165.2	6.99	2.08
10	Meghalaya	157.6	5.7	157.3	7.09	-0.30
11	Orissa	161.9	6.1	163.0	6.40	1.10
12	Punjab	167.6	6.3	168.3	7.01	0.73
13	Uttar Pradesh	165.3	6.1	164.4	6.76	-0.88
14	Uttarakhand	164.9	6.2	164.7	6.54	-0.25
	Total	163.6	6.3	164.5	6.92	0.88

Table 5. Mean Stature and percentile among Indian population (Ethnic/Caste group)

S.No.	Population/Ethnic Groups	Age(Years)			Stature (cm)		Percentiles		
		N	Mean	SD	Mean	SD	10th	50th	97th
	Scheduled Tribe								
1	Agaria	150	36.5	9.7	165.8	5.7	159.4	166.3	175.2
2	Andh	50	34.3	10.8	161.4	4.8	154.7	162.0	172.7
3	Banjara	100	35.3	10.3	162.6	5.4	154.7	162.8	172.7
4	Bhil	846	32.8	10.5	162.3	5.7	154.6	162.4	172.5
5	Bhuiya	246	34.7	9.4	157.5	6.0	150.0	156.8	170.2
6	Dubla	50	29.0	8.5	160.9	6.3	152.6	160.4	174.4
7	Gauda	50	36.8	8.1	163.4	3.4	158.9	164.0	168.9
8	Gond	1104	35.6	10.3	162.2	5.5	155.0	162.2	172.4
9	Ho	50	32.1	8.4	160.2	4.4	155.4	159.3	173.5
10	Kachari	148	35.6	11.3	162.2	5.4	155.5	162.4	172.0
11	Karan	200	34.6	9.2	163.4	6.1	156.5	163.3	175.0
12	Kathodi	50	30.9	8.5	161.5	5.1	155.3	161.5	173.0
13	Khond	100	35.8	9.6	156.3	4.7	150.0	156.8	166.0
14	Koch	150	35.4	12.6	162.6	5.7	156.0	162.5	173.6

15	Kol	200	36.6	10.3	161.2	5.7	153.6	160.5	172.1
16	Korku	150	37.2	10.9	162.3	5.4	155.1	162.4	172.4
17	Korwa	51	33.6	9.4	155.1	6.5	144.4	154.7	166.5
18	Lalung	49	34.2	9.2	160.1	6.5	149.6	159.6	173.3
19	Mahadeokoli	100	37.4	10.3	163.1	6.0	154.1	163.4	174.5
20	Majhi	50	33.5	11.1	158.4	5.7	150.7	158.5	169.9
21	Mech	50	37.9	11.1	160.3	4.4	154.2	160.5	167.8
22	Miri	50	36.9	12.2	159.3	5.8	152.0	159.2	170.8
23	Munda	148	34.0	10.3	158.3	6.1	150.9	158.2	170.4
24	Oraon	298	31.5	10.3	161.4	5.5	154.6	161.4	173.5
25	Paroja	50	33.6	6.8	160.1	5.8	151.4	160.3	171.9
26	Pnar Khasi	49	31.4	11.3	157.6	5.7	150.5	156.7	169.3
27	Rabari	50	31.2	7.2	166.3	6.5	158.9	166.9	180.8
28	Sahariya	204	32.4	9.7	162.8	6.0	155.2	163.2	172.5
29	Santal	347	34.1	10.7	160.7	5.2	153.5	161.1	170.4
30	Santhal	106	32.5	9.7	160.3	5.3	153.4	160.0	171.3
31	Savara	200	33.8	8.8	158.7	5.5	151.6	158.9	168.5
32	Sonar	51	35.9	8.0	162.6	5.5	155.8	163.3	173.1
33	Tharu	50	28.8	10.4	164.9	5.2	159.6	164.8	176.2
34	Warli	50	32.5	10.4	160.4	5.6	152.9	161.0	169.8
	Schedule Caste								
35	Balai	497	35.5	10.6	162.7	6.4	154.3	162.8	175.5
36	Bauri	50	35.8	9.8	163.2	5.0	155.9	163.9	170.3
37	Bhantu	50	29.5	9.6	165.9	5.3	158.9	166.5	176.5
38	Chamar	1939	32.8	11.1	163.2	6.1	155.5	163.2	174.5
39	Chamar (Jatav)	1062	34.7	10.7	163.7	6.1	156.2	163.7	175.3
40	Chambhar	150	33.4	11.9	161.8	5.4	153.9	162.2	172.1
41	Jat	199	34.7	12.1	168.2	5.9	161.4	168.2	179.7
42	Ghasi	200	35.5	9.7	159.7	4.8	154.4	159.0	170.3
43	Harijan	200	37.8	10.5	165.7	5.3	158.6	166.0	175.0
44	Kahar	50	33.4	10.4	164.6	7.0	156.1	164.2	178.8
45	Khati	50	33.0	8.8	163.5	6.0	155.3	163.5	174.2
46	Koli	50	36.2	8.5	162.9	7.1	154.3	162.1	182.7
47	Kori	150	34.6	10.7	162.6	6.1	154.2	162.2	174.6
48	Kumhar	300	34.1	10.6	162.1	5.9	154.5	161.8	172.2
49	Mahar	1300	33.4	10.5	161.8	5.9	154.4	161.6	173.1
50	Mang	551	33.2	10.3	162.2	5.7	154.9	162.2	173.4
51	Mehra	201	40.0	12.0	160.7	5.0	154.5	160.4	169.9
52	Mehtar	50	36.6	13.6	157.1	5.2	150.9	156.7	168.3
53	Pana	50	36.2	9.8	159.5	5.7	151.3	160.2	171.2
54	Pasi	248	31.1	10.2	162.6	5.7	155.5	162.9	172.8
55	Satnami	150	35.8	11.3	161.3	5.2	155.0	162.0	171.6
56	Shilpakar	166	32.0	10.6	163.2	6.3	155.8	162.8	176.0

57	ShilpakarDorji	50	30.6	10.1	162.4	4.9	154.9	163.1	170.5
58	ShilpakarMistri	50	29.9	10.6	162.5	5.5	154.5	162.7	173.4
	Other Backward Caste								
59	Ahir	1549	34.5	10.8	164.7	6.0	156.9	164.7	175.5
60	Ahom	100	36.0	13.6	162.0	5.6	154.5	161.9	173.5
61	Arakh	50	33.8	13.0	163.7	6.4	155.0	163.9	177.8
62	Barala	51	35.8	11.2	162.4	6.2	154.4	162.9	175.3
63	Bhandari	50	36.4	10.1	162.6	7.0	153.7	162.5	177.9
64	Bhar	50	30.9	9.3	162.3	6.0	153.7	163.2	174.7
65	Charan	50	37.0	12.1	168.3	6.2	161.6	167.8	184.0
66	Chasa	100	36.6	9.5	162.2	5.6	155.1	161.9	173.2
67	Gujar	200	34.3	11.0	167.4	6.7	159.0	167.7	180.6
68	Jugi	148	37.6	9.7	163.5	5.6	156.4	163.5	176.3
69	Kachi	324	35.5	11.1	163.1	5.4	156.0	163.2	173.3
70	Kaller	50	37.6	11.5	163.0	6.8	155.0	163.4	174.6
71	Kannar	55	36.9	11.6	162.5	7.3	152.6	163.4	175.8
72	Kewat	100	34.1	10.6	161.4	6.4	153.5	160.8	175.7
73	Kulmi	50	33.6	13.4	166.0	6.8	156.9	167.6	179.0
74	Kumbhar	1665	34.7	10.5	161.8	5.8	154.4	161.7	172.9
75	Kunbi	251	27.8	9.0	162.8	5.8	155.5	163.0	173.5
76	Kurmi	699	33.9	11.0	165.1	5.8	157.5	165.0	176.5
77	Kurumbanshi	51	38.8	12.4	163.7	6.0	155.2	163.5	176.7
78	Lodha	51	34.2	9.9	164.7	5.1	156.6	165.4	173.9
79	Lodhi	450	35.4	10.8	164.2	5.6	157.2	164.0	175.5
80	Lohar	300	33.2	11.9	163.6	6.3	155.9	163.8	176.4
81	Lora	56	37.5	9.2	163.9	6.9	154.3	164.0	177.6
82	Mangela	50	35.3	12.4	162.8	4.8	157.8	162.2	174.1
83	Panka	57	37.2	12.5	157.4	6.5	148.6	157.5	169.4
84	Rawat	52	39.4	10.4	156.8	5.5	150.1	156.7	168.4
85	Sainee	50	29.8	11.4	164.4	5.6	155.5	165.1	174.7
86	Saini	150	36.7	12.5	166.8	5.1	160.0	166.9	175.8
87	Sainthwar	50	32.7	10.7	163.6	6.6	154.5	163.1	180.4
88	Sonr	56	32.1	9.4	162.1	7.1	152.8	162.3	176.6
89	Tanti	355	34.9	9.6	158.8	5.7	151.4	158.9	169.3
90	Teli	2711	34.4	11.0	162.7	6.0	155.2	162.6	174.1
91	Thakur	150	31.9	10.3	168.4	6.4	160.1	168.5	180.3
92	TiroleKunb	30	31.0	11.5	161.9	6.0	154.7	161.2	172.3
93	Vankar	149	33.5	10.7	161.9	5.7	154.7	161.2	173.3
	General Caste								
94	Ahik	50	37.2	11.9	166.2	6.2	157.3	166.2	178.6
95	Baghwan	49	34.2	12.9	162.1	6.6	153.7	161.8	176.7
96	Brahmin	6912	34.6	11.3	165.4	6.1	157.5	165.3	177.0
97	Dusadh	200	34.1	12.0	160.3	6.6	152.5	159.7	173.0

98	Goala	346	34.1	10.1	162.1	6.3	154.4	161.8	174.0
99	Jat (Sikh)	547	37.1	11.9	169.3	6.4	161.5	169.0	181.6
100	Kanbi	299	34.1	10.1	164.3	6.8	154.8	164.8	176.5
101	Kayastha	348	34.9	12.5	165.1	6.4	156.4	164.8	177.5
102	Keota	202	34.9	9.5	163.4	5.4	155.8	164.0	173.1
103	Khandayat	158	33.2	9.2	162.8	6.0	154.8	163.1	172.6
104	Khetri	200	37.7	10.2	170.6	6.9	162.1	170.1	181.9
105	Koiborta	149	33.0	12.5	160.2	6.2	152.2	160.0	171.5
106	Kolita	573	34.6	11.7	161.8	5.8	154.2	161.8	172.4
107	Kolta	50	36.0	10.5	164.0	5.7	157.2	164.4	175.7
108	Mahasa	100	37.9	10.6	161.1	6.1	152.6	161.3	174.0
109	Maratha	954	32.2	10.0	163.8	6.1	155.9	163.6	176.0
110	Muroo	50	33.5	11.2	165.9	5.2	159.8	166.0	177.3
111	Nulia	205	32.9	8.1	161.4	5.4	154.4	161.1	170.9
112	Patidar	150	34.0	10.6	165.1	5.5	159.1	164.9	177.4
113	Rajbanshi	50	33.9	11.2	161.4	6.0	152.5	160.9	171.7
114	Rajput	2597	34.1	11.3	166.3	6.1	158.3	166.4	177.8
115	Saharuja	50	33.2	10.7	162.3	5.7	156.4	161.1	173.2
116	Vaishya	100	34.7	11.2	165.6	5.6	158.0	165.8	175.7
	Religious Group								
117	Muslim	5145	33.7	11.1	164.3	6.1	156.5	164.2	175.5
118	Jain	798	34.0	11.3	163.7	6.0	155.8	163.8	175.2
	Total	43952	34.2	11.0	163.7	6.3	155.6	163.6	175.5

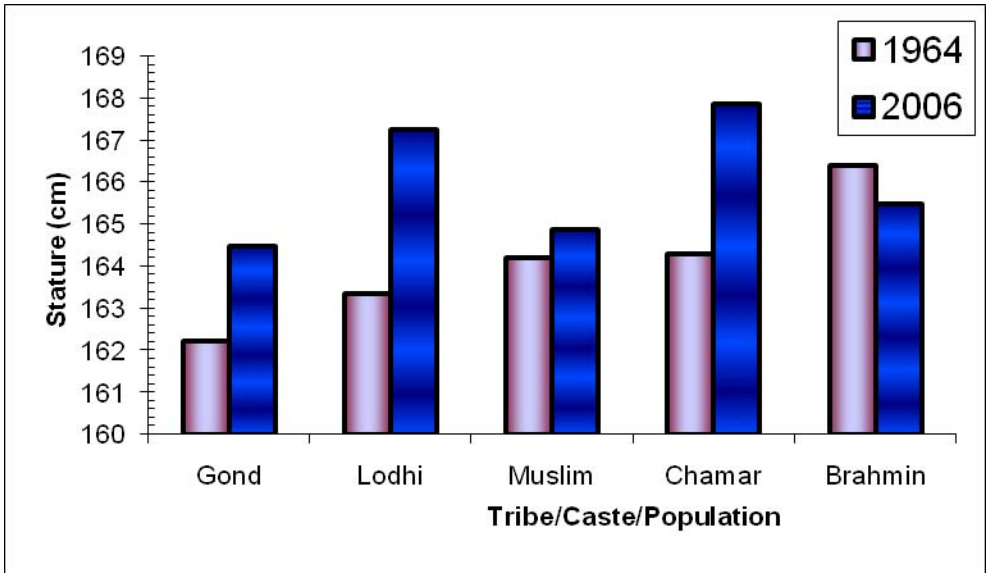
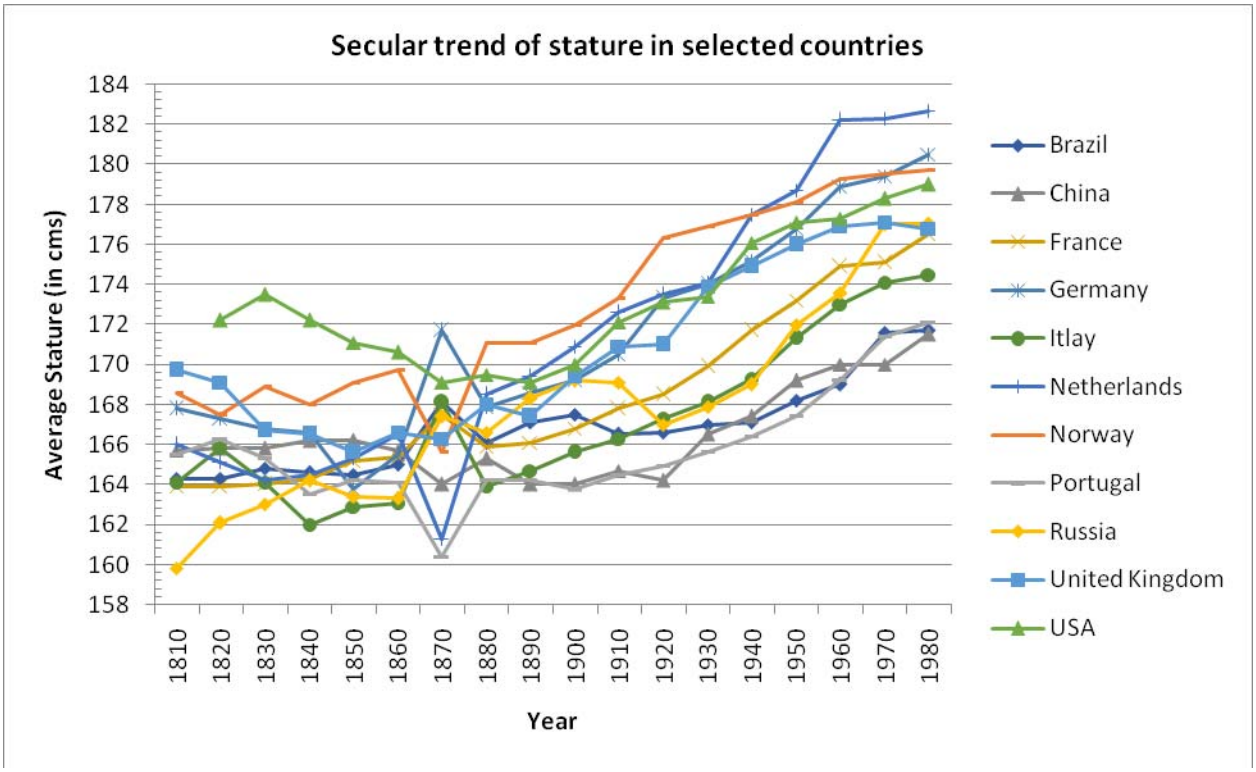


Figure 7. Bar diagram showing comparative mean stature among five different population of central India during 1964 and 2006 (t=-3.29, p>0.001; F=4.6, p>0.04)



Source: https://ourworldindata.org/human-height

Figure 8. Secular trend of stature in selected countries of the World in between 1810 to 1980.

Figure 9. Scattered plot diagram showing correlation and regression of stature and human development index (HDI)

To understand the secular trend in global perspective, country wise data on average stature was obtained for 151 countries. The mean stature of selected countries is plotted as line diagram (Figure 8) indicate that the average stature of human being is increasing all around the globe.

To find out the role of development in the increment of human stature, here average stature of 90 countries was analyzed in context of their human development index (HDI). It was found that the HDI has positive and significant correlation with the mean stature ($r^2 = 0.391, p < 0.001$) (Figure 9), Further it is evident from scattered plot diagram that European countries are leading in both i.e human development index as well as in stature.Denmark and Netherland are at top. On the other side, the countries of North America have wide variation in terms of stature. United States (USA) and Canada stand with European countries, whereas Latin American countries like Guatemala, Honduras and Nicaragua stand at bottom of scattered plot diagram with Asian countries. Most of the African countries are clustered and scattered separately with low to moderate human development index. They are in

between of European and Asian population by the point of view of stature. The Latin American Countries included in the investigation fall under the regression line, stand mostly with African and Asian countries.

Most of African countries have low to moderate HDI; which indicate about their poverty; still they have higher average stature and clustered together above Asian countries (Figure 9).For example, countries like Chad and Senegal has quite low HDI (0.328 and 0.459) as compared to Japan (HDI= 0.901, Asian countries), still they have higher average stature (173.3 and 174.3 cm) thanJapan (171.7 cm). Among African countries only Madagascar (162.9 cm) is exception in stature that stands near Nepal (163 cm), which is a south Asian country). Asian countries like Vietnam and Philippines are at the bottom by the point of view of mean stature.

It is apparent from bivariate linear regression analysis (Table 6) that there is significant correlation and regression between stature and human development index (HDI), life expectancy, gender inequality index, total fertility rate, infant mortality rate and percentage of population (15-64 yrs). The human development index and life expectancy have positive regression on stature indicates that where living condition is better alongwith good medical care, better educational attainment and enhanced livelihood opportunities the adult male stature is higher and increasing. Simultaneously, they also have extended life expectancy. In other words, the tall individuals live longer as compared to short one. Reverse can be seen in case of fertility and mortality indicators as well as gender inequality index. Better economic condition of a country is dependent on its working population of 15-64 years of age group, hence it also has positive regression on stature.

Table 6. Regression coefficients and F-statistics of average stature (dependent variable) and predictors HDI etc.

S.No.	Independent Variables	Coefficients of regression				F-statistics	
		R^2	β (Unstandardized)	SE	*t* Value	F Change	P Value
1.	Human Development Index	0.398	17.3	2.27	7.6	58.2	0.001
2.	Life expectancy (male)	0.201	0.22	0.05	4.6	21.9	0.001
3.	Gender inequality index	0.458	-17.94	2.18	-8.2	67.5	0.001
4.	Total fertility rate	0.146	-1.3	0.34	-3.8	15.01	0.001
5.	Infant mortality rate	0.198	-0.07	0.02	-4.6	21.8	0.001
6.	% Population (15-64 yrs)	0.157	0.29	0.07	4.0	16.1	0.001

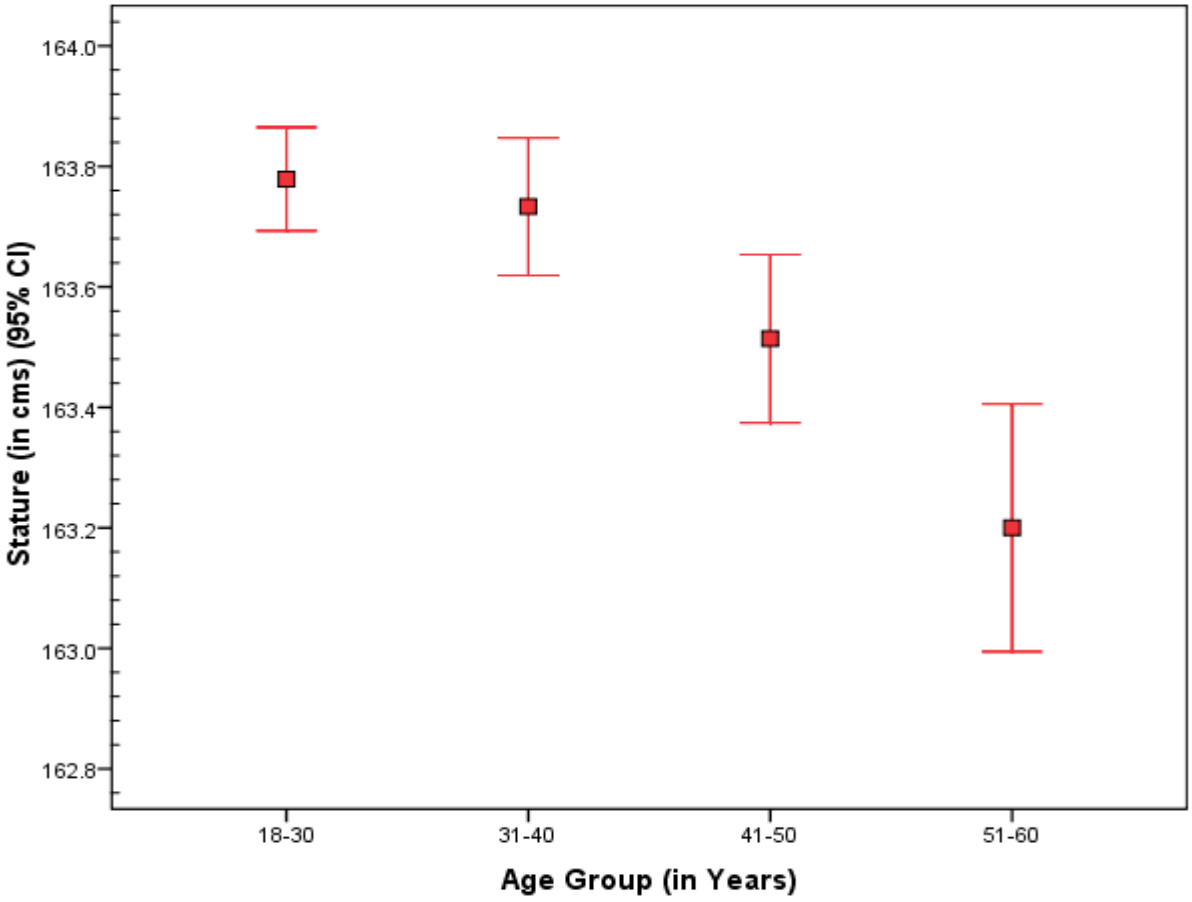


Figure 10. Error bar diagram showing significant difference of stature among the cohort of 18-30 years and 41-50 and 51-60 years of age.

Discussion

Wide variations of human stature in general are attributed by genetic structure, geo-climatic setup, historical migration and socio-economic development, but in context of Indian population, social structure and caste hierarchy has also played a pivotal role. Bharati et al. (2005) have pointed out that "a variety of natural, geophysical, or topographical regions (with highest mountain ranges, rivers, delta region, vast plateaux, sea-coast, deep jungles) are conducive not only to the rich biodiversity but also for the human settlements. These geophysical settings have acted as durable protective mechanisms and communication barriers for the settlement of several historical migrations of diverse ethnic communities that sustained to exist since prehistoric times". This has lead to the unique stratified population structure consisting of thousands of communities of castes, sub-castes, tribes characterized by endogamy, culture and a variety of subsistence practices, dialects, kinship pattern, a variety of food habits, customs and health practices, etc. (Malhotra and Vasulu 1992, Singh et al. 1994).

The caste system is a typical characteristic of the majority of Indian populations (Adak et al. 2006); which are localized groups and are geographically structured and show wide differences in socio-cultural and linguistic factors. Further, majority of the tribes have discontinuous distribution and small population size. Their genetic fate is guided by genetic drift and show unique frequencies of genetic characters and absence of geographic clines. Both the tribal and caste distribution have a strong bearing in the making of biological diversity of Indian populations, but how exactly that is reflected, and the extent and the magnitude as well as patterns of variation are the subject of investigation (Bharati et al. 2005). The caste and tribe wise vivid details of adult stature among Indian population obtained by present analysis corroborate above hypothesis.

The present findings further establish that there is difference in stature among individuals of different caste group; affluent castes are tall in stature as compared to deprived group of same geo-climatic and socio-economic

milieu. According to Singh et al. (1994) there are at least 4635 communities comprising castes, sub-castes and tribes of diverse ethnic, linguistic, religious and cultural stocks in different geographical regions of the country. This stratified population structure and the nature of this vast diversity is further corroborated by present findings. Bharati et al. (2005) truly pointed out that it is interesting to investigate the extent and nature of biological diversity and the factors that maintain the diversity and its micro-evolutionary process.

In India each caste group has definite traditional occupation. From many generations they were practicing the same occupation, marrying within own caste group. This practice of endogamy and traditional occupation has impacted their stature also (Gautam 2007 and 2008). As the poor yielding occupation was having more investment and less income creating a persistent environment of poverty, starvation and malnutrition and causing stunting and wasting, hence adaptation to this situation has resulted into small body size. 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 (Scrimshaw and Schurch, 1998). Shorter height is further associated with a number of consequences, such as poor cognitive development (Tuvemo, Jonsson and Persson, 1999), obstetric emergencies (Sheiner et al. 2005), and low birthweight in the offspring of short women (Kramer, 1987). Present investigation also lead to conclude that the cycle of poverty, malnutrition and stunting persistently operating among the deprived sections and resulting into small body size. The state of Meghalaya is good example of it, which have 80.5% population scheduled tribes. Nobody, in the sample was found to be in tall category. Further, a total of 30% have very short to short stature. And, even after 35 years, the scenario is unchanged, as the report of third national family health survey (NFHS 3), also has similar findings. The report states high prevalence of severe stunting (30%)among children under 5 years of age in Meghalaya. It is possible that stunting of final height in Meghalaya is determined at preschool age,and this may be one of the reasons for the negative secular trend (NFHS 3, 2007). Mamidi et al.(2011) on the basis of multiple regression analyses also reached on similar conclusion that 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.

Secular trend of height has been witnessed in developed countries since the late 19th century, as a result of improvement in nutritional status followed by socioeconomic development (Eveleth and Tanner, 1990; Krawczynski et al. 2003; Padez, 2003; Cole, 2003). From a historical perspective, the average height of Indian men in the 21stcentury is similar to the height reported for men in many developed countries in the 19thcentury (Mamidi et al. 2011). As per present investigation the average stature of adult Indian male was 163.7±6.3 cm in a span of 35 years it increased to 164.5±6.9 cm with an increase of 0.88 cm. For further elucidation of secular trend in stature among Indian population an error bar diagram (Figure 10) is plotted for cohorts of different age group 18-30, 31-40, 41-50 and 51-60 years. It is apparent that the cohorts of 18-30 years are significantly taller than 41-50 and 51-60 years. These finding corroborate Mamidi et al. (2011), they reported 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. Further they pointed out that 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).

The regional variation of height has observed among the Indian states. The populations of North-eastern states viz. Meghalaya are significantly short and population of northern states viz. Haryana and Punjab are significantly tall. Mamidi et al. (2011) also found similar variation and noticed that diet is an important indicator of height. He especially focused that intake of milk have significant relationship with the increment of height.

The analysis of global data has already established positive correlation of stature and gross domestic product (GDP) (Deaton, 2007). Further, GDP is correlated to economic growth. Therefore in the present analysis correlation of stature and human development index (HDI) is explored from global data. Human development index is a measure of health, wealth and longer life. The positive correlation of stature with HDI, again prove that stature is determined by economic growth (GDP) (Deaton, 2007) as well as overall better living conditions added by better medical care, educational attainment and extended life expectancy (Gautam, 2007).It also helps to understand the variation of stature exists among different ethnic/caste groups of Indian population. The scheduled tribes and castes have lowest mean stature indicates that they have low HDI also, which is true and require attention of government and developmental agencies.

Conclusion

No doubt, there are ongoing secular trends in height. Since last two century, the socio-economic development around the globe has resulted into increment of adult human height. But, it is not uniform; inspite it is corresponding to GDP and HDI. In India too, the younger generation are taller than their parental generations (Figure 7 and 10). Error bar diagram showing significant difference of stature among the cohort of 18-30 years and 41-50 and 51-60

years of age (Figure 10). There is significant variation of stature on the basis of ethnic group, region (state) and traditional occupation which lead to conclude that the pan-Hindu caste stratification is one of the predominant determinants of stature among the Indians (Asian), as there is rigid structure of caste system; and it is an stigma, especially for lower caste people, where the caste, in which an individual is born, decides their job profile. If an individual is born from parents of shoe maker known as Chamar (caste). He or she can't be priest even after knowing the skill of priesthood. Even, s/he can't run restaurant. S/he can't be cook or waiter in a restaurant, in a known periphery. As s/he would still be treated as untouchable, and if s/he is employed as cook or waiter, the larger bulk of customer will not go to such restaurant. Ultimately, s/he has to practice the traditional occupation of shoe making only. In this way, his/her socio-economic status, stigma, and social status remain unchanged from generation to generation. Besides caste and occupation, nutritional status was also found to be determinants of adult stature. In context of Indian population, there is complex cycle of short stature, poverty and caste hierarchy which need concerted efforts from government and non-government agencies to improve human health and alleviate poverty so that adult height and health could be improved in long run.

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