EXPLORING THE VARIATIONS IN ADULT HEIGHT OF POPULATION BY AGRO-CLIMATIC ZONES IN INDIA

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Abstract

Body height is a potential tool, that accurately reflects the average nutritional status of the citizens of a country, which indicates the interaction of genetic and environmental influences during the growth period. Various factors: poverty, food security, genes, climate change and temperature impact the food intake and human stature. This study pertains to the analysis of secondary data of National Family Health Survey (NFHS) (2015-16) which contains a district identifier. Based on the classification of Khanna (1989), we have divided the country into 15 agro-climatic zones to study the variations in body height amongst Indians. India has three height patterns and the lowest height people live in the eastern part, followed by the central and southern part, and tallest persons are in the western Himalayan regions.

We have found a negative association between percentage poor and the mean height of adult men and women. Within regions also there exist significant differences between the poor and rich. In terms of protein consumption, all those who consume quality proteins are taller than those who consume only one form of protein. The results show that even after controlling for economic status and protein consumption, the difference in mean height of men is 4 cm and women

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is 3 cm between the regions. From this, we can conclude that the characteristics of agro-climate regions and people living in that region by different racial background cannot be ignored in the explanation of variation in height in the Indian population.

Key Words: Adult height, Agro-climatic zones, race, ethnicity, poverty, protein intake

Introduction

The historical literature on stature suggests that variation in stature represents an evolutionary adaptation to climatic conditions.[1] Variation in body height in most cases give the expression of an evolved reaction norm reflecting a life-history trade-off between growth, maintenance and reproduction.[2] The height of an individual reflects the interaction of genetic and environmental influences during the period of growth. There are significant differences in anthropometric profile among populations inhabiting in different geographical zones as well as among those with different ethnic backgrounds. It indicates that the effects of both these factors on anthropometric variation are important.[3] The height of an individual reflects the interaction of genetic and environmental influences during the period of growth.[4, 5] Guha (1935) mentioned in his work on racial affinities of the people of India, the differences in physical characteristics of races and their location in India.[6] Indians are from diverse races and different climatic zones and are expected to have differences in body height.

Studies have also showed that environmental factors regulate growth in body size and the rate of biological maturation.[7,8] The study from Sub-Saharan Africa concluded that climate fundamentally influences food intake and exposure to diseases and catch-up growth at puberty.[9] On the other hand, genetic determinants of body shape and proportion are more resistant to the environment, and the body proportions characteristic of ethnic groups seem to maintain themselves across a range of environmental conditions.[10] There is an interplay between various genetic, socio-economic, and environmental factors that should be taken into consideration while making inferences on human height rather than concluding that the mother's height is the sole factor that influences the adult height.[11] A review of studies from developing countries has reported that growth differences between groups reflect environmental factors during childhood and genetic factors play a role during the adolescent years.[10] Adult size results from a blend of hereditary and environmental factors, though environmental determinants predominate. According to Eveleth and Tanner (1976), "two genotypes that produce the same adult height under optimal environmental conditions may produce different heights under circumstances of privation."[12] Moreover, inhabitants of any less developed country who reflect most closely its indigenous gene pool experience the poorest environments.[10] In the case of association between climate and stature, a modest relationship was found between temperature and sitting height and it was attributed to the development that underscore nutritional and temperature stresses in shaping human variations in body size.[13] Despite different claims of a relationship between environment and stature, a recent study from Nepal shows the evidence of variations in the height of children by agro-climatic regions.[14]

Researchers on nutrition in developing countries have focussed attention on the lack of resources in a region, while climatic and racial analyses are sporadic on nutrition issues. There are different agro-climatic regions in a vast country like India and the climatic conditions in each region impacts food production levels. Hence, the food habits of the population vary accordingly. Many studies have concentrated on the explanation of state level differences in the stunting of children. Moreover, there is less work on the adult height variations in regions of India. A lack of research on adult height by regions may be due to the scarcity of anthropometric data in the past. Nonetheless, there are studies with few cases on the adult height by region.[3] Furthermore, state-level studies of adult height are also limited. [15]

Not only is the level of food production different in various regions in India, but it also has a relationship with the development and level of poverty in the area.[16] Poverty is associated with inadequate diet and limited resources which paves the way for various infections and ultimately leading to an individual's poor nutritional status, resulting in short stature.[15] Also, people with low socioeconomic status have higher propensity to purchase a lower variety of fruits and vegetables.[17] Moreover, under-nutrition can be both a cause and a consequence of poverty.[18, 19] Hence, it is vital to examine the cause of under-nutrition. One of the essential nutrients that determine the final growth of an individual is protein.[20, 21] Studies have shown the association between consumption of different types of protein (dairy, animal and vegetable) and their combination with height.[22, 23] On the other hand, there are studies which argue that differences in an individual's nutritional status is mainly due to genetic factors.[24] Furthermore, several studies have examined the association between food security and nutritional level of children.[25-29]

Understanding and quantifying the association between agro-climatic regions, food production, adult height is vital in a vast country with so much diversity, like India. Moreover, for targeting intervention and valuable guidance for improvement of nutrition, causal mechanism response according to agroclimatic conditions will be useful.[14, 30, 31] Therefore, there is a need to examine the variations of adult height of persons living in different agro-climatic zones. It helps us to understand the level of poverty, food intake and racial factors in the difference in the height of the Indian population. This study deals with the examination of variations in adult height in India according to agro-climatic regions, taking into consideration the level of poverty and protein intake of individuals using a nationally representative sample of NFHS-4.

Methodology

This study pertains to the analysis of secondary data of National Family Health Survey (NFHS) (2015-16). The International Institute for Population Sciences (IIPS) was designated as the nodal agency for this project by the Ministry of Health and Family Welfare (MOHFW), Government of India, New Delhi. NFHS-4 provides information at district level on the height and weight of adult men and women.

In order to find the association between food availability (cereals) and the nutritional status of the population, the country is divided into 15 agro-climatic zones using the classification adopted by Khanna (1989).[32] The classification of zones by Khanna (1989) is similar to Chatterjee (1973) classification.[33] Until NFHS-3 it was not possible to generate the data properly according to agro-climatic regions of India in the absence of district level codes. NFHS-4, data is available at the district level, and identification of agro-climatic according to the classification of Khanna (1989), regions is possible from this data set.

According to Khanna (1989) the Western Himalayan Region (WHR) comprises the districts of Himachal

Pradesh, Jammu and Kashmir and Uttaranchal. The Eastern Himalayan Region (EHR) includes the districts of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and West Bengal's hilly region. The Lower Gangetic Plain Region (LGPR) covers the entire state of West Bengal, except for four districts: Darjeeling, Cooch Behar, Jalpaiguri and Purulia out of its 18 districts. The Middle Gangetic Plain Region (MGPR) consists of the districts of Bihar and Eastern Uttar Pradesh. The MGPR consist of six sub-Agro Climatic Zones, three falling in Bihar and three in Uttar Pradesh. The Upper Gangetic Plains region (UGPR) includes the districts of Western and Central Uttar Pradesh which is among the larger and very thickly populated agro-climatic zones. The Trans-Gangetic Plains region (TGPR) consists of the districts of Chandigarh, Delhi, Haryana, Punjab and only one district of Rajasthan i.e. Ganganagar District. In the Eastern Plateau and Hills region (EPHR) the districts of Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Orissa and West Bengal are included. And this is the largest agro-climatic zone covering about 400 thousand square kilometres of geographical area. The Central Plateau and Hills region (CPHR) includes the districts of Madhya Pradesh, Rajasthan and Uttar Pradesh and is centrally located. The Western Plateau and Hills region (WPHR) encompasses the districts of Madhya Pradesh and Maharashtra. This zone comprises a major part of Maharashtra, parts of Madhya Pradesh and one district from Rajasthan. The Southern Plateau and Hills region (SPHR) covers the districts of Andhra Pradesh, Karnataka and Tamil Nadu. The East Coast Plains and Hills region (ECPHR) comprises the districts of Tamil Nadu, Andhra Pradesh, Orissa and Pondicherry. The Western Plains and Ghats region (WPGR) includes the districts of Goa, Karnataka, Kerala, Maharashtra and Tamil Nadu. This zone is famous for plantation crops and spices. The Gujarat Plains and Hills region (GPHR) encompasses the districts of Gujarat, Dadra and Nagar Haveli, Daman and Diu. This zone covers the entire state of Gujarat. This zone can further be divided into South, Middle, North and Saurashtra-Kutch regions. The Western Dry region (WDR) comprises the districts of Rajasthan. The last zone is the Island Region (IR) which includes the districts of Union Territory of Andaman and Nicobar Islands and Lakshadweep Islands.

Taking into consideration the significance of different types of proteins, we have divided protein consumption into three parts. First is a dairy protein which included the consumption of milk or curd, second is a vegetable protein which consisted of pulses consumption and third is an animal protein which included the consumption of egg, fish, chicken or meat. Percentage of households falling in the low and lowest quintiles level is categorized as poor.

Statistical Analysis

In this study, we have calculated mean height and standard deviation of it for men and women separately for each zone as well as at district level considering unit-level data. To understand the differences in the group mean height by categories, done the test of significance for each pair. The level of confidence and alpha values are prefixed with 95% and 0.05, respectively.

Linear regression carried out separately for women and men to study the association of agro-climatic regions and adult height of the population. For the analysis, we have used district as a unit rather than unit-level data of women and men. When both the absolute and relative information size is large, aggregate data analysis results will most likely be reliable. The individual-level analysis is only useful if individual characteristics play a role in the explanation.

Results

Variations in adult height by age groups

In order to understand the differences in adult stature of men and women within a diverse country like India, we selected agro-climatic regions. This helped us to examine body heights with a diversity of the agriculture production, food habits of the people living in these regions.[30] Also, the groups selected have similar climatic conditions, occupation and other lifestyle habits.

We selected two consecutive age groups for men and women (age group 20-29 and 30-39 for women and age group 25-34 and 35-49 for men) to examine temporal changes in height. These age groups were selected, considering the differences in the physical maturity of women and men. There are significant differences in the height of the men and women across different agro-climatic zones in the selected age groups. The mean height for women is as low as 150 cm to as high as 156 cm between the regions. Similarly, the mean height for men is as low as 161 cm to as high as 167 cm. The difference between men and women in height is more than 10 cm in all the regions. On average, the height ratio of male-to-female is 1.07, and it is similar to global standards.[34] According to Bogin, 1999, Eveleth and Tanner 1976, women both start and stop their growth spurt at an earlier age, and it results in the differential growth pattern with men.[12, 35]

The Western Dry region (WDR) comprising the districts of Rajasthan performed well in terms of the mean height of women. The Trans-Gangetic Plains region (TGPR) consisting the districts of Chandigarh, Delhi, Haryana, Punjab and only one district of Rajasthan has tall men. All the people living in this region belong to a similar race.[6] During the British period, people living in these regions were considered a martial race because of their stature.[36]

The lowest mean height of women is observed in the MGPR region, followed by the EHR region of India. While for men, the lowest mean height is observed in the region of EHR. According to Guha (1935), people living in the region of EHR belong to Mongoloid race. In the MGPR region, the population mostly belongs to the Mediterranean race.[6]

On average women in the age group, 20-29 are taller than the women in the age group 30-39 in most of the agro-climatic zones. In the case of male too, the same scenario is found for the age group 25-34 in comparison to age group 35-44. Furthermore, significant differences for females are found in twelve zones and for males in eight out of 15 zones of India. Similar results are found in the state level analysis from NFHS-3 data.[15] For further analysis, we considered only the 20-29 age group of women and for males 25-34. Looking at Figure 1 and 2, we can conclude that India has three height patterns. The lowest height people are living in the eastern part, followed by the central and southern part, and tallest persons are in the western Himalayan regions. International comparison of the mean adult height of Indian population considering the entire population may give misleading interpretations.

Variations in adult height by level of poverty in the region

Socio-economic factors such as poverty determines the nutritional status of an individual; hence it is vital to know the economic status of the population in the zone. Region-wise analysis of socio-economic status will help us to understand the determinants of height in the region. Table 2 illustrates the distribution of poor and rich among various agro-climatic zones of India. The lowest percentage of the poor population is found in the TGPR region, followed by WPGR and IR. Whereas the highest per cent of poor population are found in MGPR region followed by EPHR region. The level of poverty between different agro-climatic zones ranges from as low as 7% to as high as 72% suggesting the vast economic disparity between India's agro-climatic zones.

An attempt is made to study the association between poverty level of agro-climatic region and mean height of adults. Figure 3 presents the association between the percentage of the poor and adult mean height of males in 25-34 and females in 20-29 age groups. This figure depicts the negative association of stature with poverty. The regions with a high percentage of poor have short stature persons. A similar pattern is found in Unisa and Barkotoky (2017).[37] In Figure 4, a district wise analysis of percentage poor and mean height of men 25-34, and women 20-29 was carried out to see the relationship. The resulting analysis indicated the negative relationship between poverty and mean height of males and females. However, there are few exceptions in the district level analysis as well as agro-climatic zones (WDR zone) where the association is not visible. Hence, we can conclude that poverty, is not the sole factor that impacts the nutritional status and adult height of an individual.

Variations in adult height within region by economic status

Huss-Ashmore and Johnston, 1985, concluded in their study that the difference within the region between low and high socioeconomic status is more than between the regions.[10] In this study, too, we found a difference in the mean height of adults belonging to rich and poor wealth quintile in the region (Table 3). Differences in mean height by economic status in each region for women and men are significant (Except in the case of males in the IR region). However, the magnitude of difference between these categories is not large except for a few exceptions. Hence, we can conclude that within a region, it's the economic status that plays a role in the variation of the height of the population.

Variations in adult height within region by consumption of proteins

Studies in the developing world have reported, the prevalence of mild to moderate protein-energy malnutrition (PEM).[38] Animal sources provide all essential amino acids, whereas vegetable sources generally lack one or more of the essential amino acids.[39] Hence, it is crucial to examine the consumption of proteins by the Indian population. The protein consumption data is of the current situation of the adults. We have assumed that they might have taken the same type of food during the time of growth. One recent study found that food habits do not change at different stages of the life for women.[40]

Considering the quality of protein and considering the food consumption data of NFHS-4, consumption of protein has been divided into three categories that are a dairy protein, animal protein and vegetable protein. Table 4 provides information on men and women daily consuming at least two types of protein in each agro-climatic zone. In most of the population, the consumption of cereal and pulses is daily. However, if the consumption is more than two types, then means people may be consuming good quality protein from dairy or animal sources. It's seen that the largest proportion of men and women daily consuming at least two types of protein reside in the SPHR region of India, i.e. 45.1% and 46.1%, respectively. Furthermore, the men and women residing in the EPHR region consume less amount of protein which stands second in terms of poverty with 65.1%.

Table 4 presents the mean height of women and men by their protein consumption status. The first column in this table constitutes of women and men who consume at least two types of proteins. The difference in the mean height of women by protein consumption status ranges from as low as 0.19 cm to as high as 1.31 cm in the regions. Adults who consume a higher number of protein have a higher height in comparison to those who consume less number of proteins. In the case of women, differences in height are significant in all regions except IR, whereas in the case of men, it is not significant for WHR, SPHR, WPGR, GPHR and IR regions. From this analysis, we conclude that protein plays a vital role in achieving the maximum height of the population.

Multivariate analysis of adult height

Table 5 and 6 present linear regression analyses result of the height of women and men. In these analyses, we have considered district as a unit of analysis within each agro-climatic region. Hence, independent variables are agro-climatic regions, level of poverty and consumption of at least two types of proteins. The goodness of fit for regression models are found satisfactory with R Square and adjusted R Square is close and explained considerable variation in height by the independent variables (Women – R square 0.685; Men –R Square 0.469). The differences are significant in the height of women and men after controlling for the poverty and consumption of proteins. The difference of mean height between the Western Himalayan region and Eastern Himalayan is around 2.4 cm for women and 3.7 cm for men.

Discussion

Anthropometric measurements such as height and weight have historically been regarded as a marker of health. It has long been a focus of research in a range of social science disciplines. Studies suggest that adult height is a useful marker of variation in cumulative net nutrition, biological deprivation, and standard of living between and within populations in developed countries.[11] It was challenging to study the broad pattern of height variation in India due to the absence in past of standard anthropometric measurement from a large representative sample of the Indian population. In this study, adult height variations in India is studied by agro-climatic zones using a nationally representative sample of NFHS-4. It was possible because NFHS-4 provided data at the district level for the first time, and it is feasible to classify the zones according to the classification given by Khanna (1989). The authors in the earlier study tried to examine the mean height of adults in various agro-climatic using previous rounds of NFHS; however, zones were not properly defined due to data limitation.[37]

It is interesting to find that the adult height of the population is increasing at 1% points for men and women between two consecutive age groups of ten years. The growth in height shows the temporal improve height at a slow pace. The variation in height between the geographic regions are visible from the bivariate analysis and maps. An Indian map indicating heights for men and women gives a very distinct classification of the country's population by regions. The lowest height persons are found mostly in Eastern Himalayan Region (EHR), Eastern Plateau and Hill Region (EPHR), Middle Gangetic Plain Region (MGPR) followed by the Lower and Upper Gangetic Plain Regions (LGPR and UGPR). Central and southern regions of India (CPHR and SPHR) have a little higher height than the eastern and Gangetic regions. The tallest persons are found in the Western Himalayan Region (WHR) and Trans-Gangetic Regions (TGPR), Western Dry Region (WDR). However, in case of the mean height of women from GPHR, they are similar to the Western Plateau and Hill Region (WPHR).

Most studies from developing countries attribute the difference in height by geographic regions to low resources and economic conditions of the population in the region.[41] The level of poverty is lowest in the TGPR region with 7.1% and highest in the MGPR region (72%) followed by EPHR (65% and EHR (59%) regions. EPHR and EHR regions consist of tribal population, and the area is mainly dominated by hills and suffers from lack of power supply, transport and communication resulting in industrial backwardness and thus impacting the zone's social and economic status.[42] The MGPR region which consisted of the districts of Bihar and Eastern Uttar Pradesh has a high level of poverty.[42,43] There is a big difference in the level of poverty, but the difference in height is only 4 cm between MGPR and TGPR. On the other hand, the WDR area where the level of poverty is moderate but the height of the population is similar to the TGPR region for both men and women. The question then arises, can we attribute this difference only to the economic status of the population or are there other important factors that have been ignored in ascribing differences to the poverty stricken population.

Within region differences in height may be attributed to unequal income distribution.[10,44] The difference in the mean height of men belonging to the rich and poor household is lowest in the region of WPGR. The lowest difference within WPGR region can be attributed to the development that took place in this region as compared to other regions in terms of basic amenities, education, transport, roads, communication, etc. [45] Being a high rainfall zone, agriculture can be taken up the entire year and also it is the primary producer of many export-oriented foods products.[45]

Studies have attributed the variation in height to food production and consumption of protein in each region[44, 46-48] It may be noted that the type of food consumption in Indian states is significantly different and it is visible from the different studies.[49,50] In this study consumption of at least two types of protein is considered as it represents the quality and variety of proteins . Once enough food has been produced in the region, people then can move on to the nutritional quality of food. This notion is supported by our finding, which shows that SPHR region, which witnessed increasing agricultural production and income of the people increased the demand for processed and high-quality foods.[45] Thus, the largest proportion of men (aged 25-34 years) and women (aged 20-29 years) in this region consumed at least two types of proteins daily. The study also tries to understand the impact of protein consumption on the mean height of the adults. It can be seen that lowest difference in mean height of the men and women has been observed in the WHR region between those who consume at least two types of proteins daily and among those who do not consume at least two types of proteins daily. The use of new technology for the development of production is widespread in WHR.[46] Although the differences in height by consumption of proteins types is significant, the magnitude is minimal. The consumption of rice is dominated in the Eastern and Southern part of India, whereas in WHR, TGPR and WDR wheat is the predominant cereal.[50,51] In Central, UGPR, and MGPR regions, a mixed type of cereals, i.e. rice and roti, are consumed. All those who consume, rice and legumes without animal proteins have lower nutrient density, and that can negatively influence the height.[23]

From the multivariate analysis carried out separately for men and women, it is very evident that after controlling for the poverty and protein consumption, agro-climatic regions have higher beta values and R square is also sufficiently large. The differences between Western Himalayan Region and Eastern Himalayan Region for men is 3.7 cm, and for women, it is 2.4 cm. Figure 5 and Table 7 present the races and location of the Indian population.[6, 53-55] There is a very significant association of agro-climatic regions with the height of population, and each agro-climatic region dominates different races. Hence, based on our regression analysis, we conclude that in the explanation of stature of population, race, and the region cannot be ignored by saying that intermixing of races have taken place historically in India.[3,10] We found very distinct differences between the Mongoloid, Proto-Australoid and Indo-Aryan races. People who are from the Mediterranean and Dravidian races, their height is between Mongoloid and Indo-Aryan races. All the people are growing, but growth is unequal. [56]

Conclusion

This study revealed that heredity and climatic conditions play a significant role in the variation of the height of population in India. Further analysis of race wise differences by considering other parameters of anthropometric data and climatic condition by seasons in each geographic region will help us to understand the nutrition status of the population. We also examined the only association of overall protein intake on the adult height. Thus, scrutiny of different types of proteins, consumption of cereals and its impact on human stature are therefore desirable in future. Policymakers should take into consideration the paramountcy of agro-climatic zones and economic status while making strategies to tackle the problem of malnourishment in a country like India.

Table 1

Mean height of adults according to Agro-climatic regions and age groups, 2015 – 2016

	Women					Men				
Agro climatic zones	20-29		30-39		t-statistic	25-34		35-44		t-statistic
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
WHR	154.47	6.21	154.24	6.28	4.01*	166.56	7.19	166.29	6.63	3.83*
EHR	150.89	5.9	151.14	6.09	-6.61*	161.82	6.64	162.08	6.01	0.64
LGPR	151.30	5.68	151.14	5.51	2.02*	163.28	6.09	162.27	6.78	1.16
MGPR	150.18	6.37	150.15	6.42	0.60	162.49	6.71	162.05	6.97	2.21*
UGPR	151.25	5.93	150.89	5.97	6.55*	163.97	6.92	163.19	6.54	4.09*
TGPR	154.46	5.9	154.61	5.98	-4.03*	166.95	6.38	166.43	6.44	1.46
EPHR	150.76	5.59	150.68	5.56	-1.15	161.86	6.65	161.59	6.4	2.02*
CPHR	152.94	5.84	152.74	5.74	2.27*	164.84	7.21	164.43	6.87	2.34*
WPHR	152.71	6.17	152.41	6.2	6.38*	164.64	8.17	163.46	6.98	3.94*
SPHR	152.71	6.1	152.36	6.18	2.57*	164.04	7.55	163.35	7.04	1.87
ECPHR	152.44	5.93	152.15	5.86	2.65*	164.37	7.29	163.48	6.89	2.15*
WPGR	153.62	6.59	153.68	6.34	1.94*	164.76	8.03	164.72	6.93	1.66
GPHR	153.18	6.02	152.69	6.24	2.89*	165.16	7.36	164.19	6.9	2.25*
WDR	155.58	5.69	155.71	5.49	-1.20	166.92	6.84	166.1	6.49	1.57
IR	152.99	5.95	153.61	6.54	-2.06*	163.59	6.73	163.68	7.85	0.13

*P-value significant at 95% CI

FIGURE 1
Mean height of men 25-34 years by agro-climatic regions

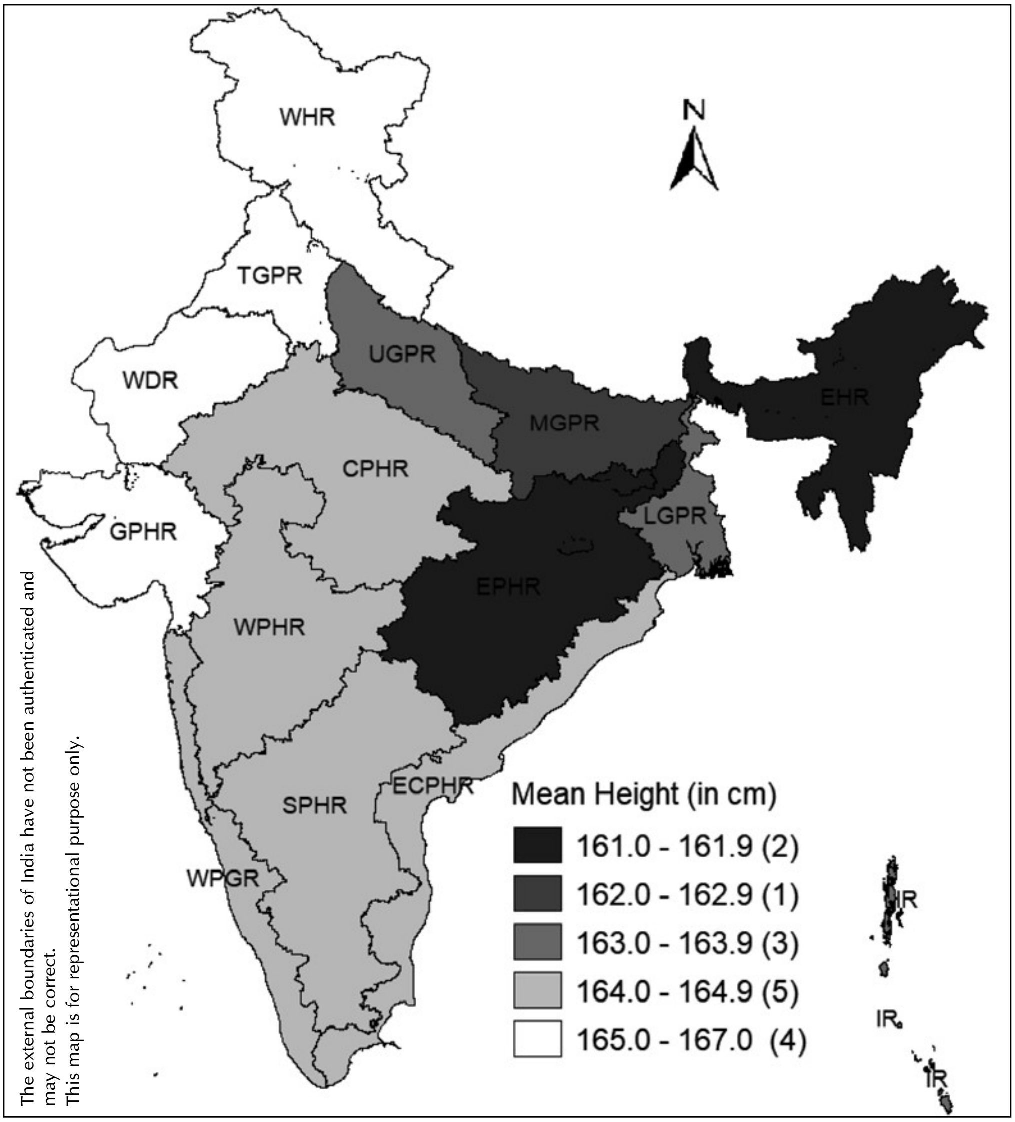


FIGURE 2
Mean height of women 20-29 years by agro-climatic region

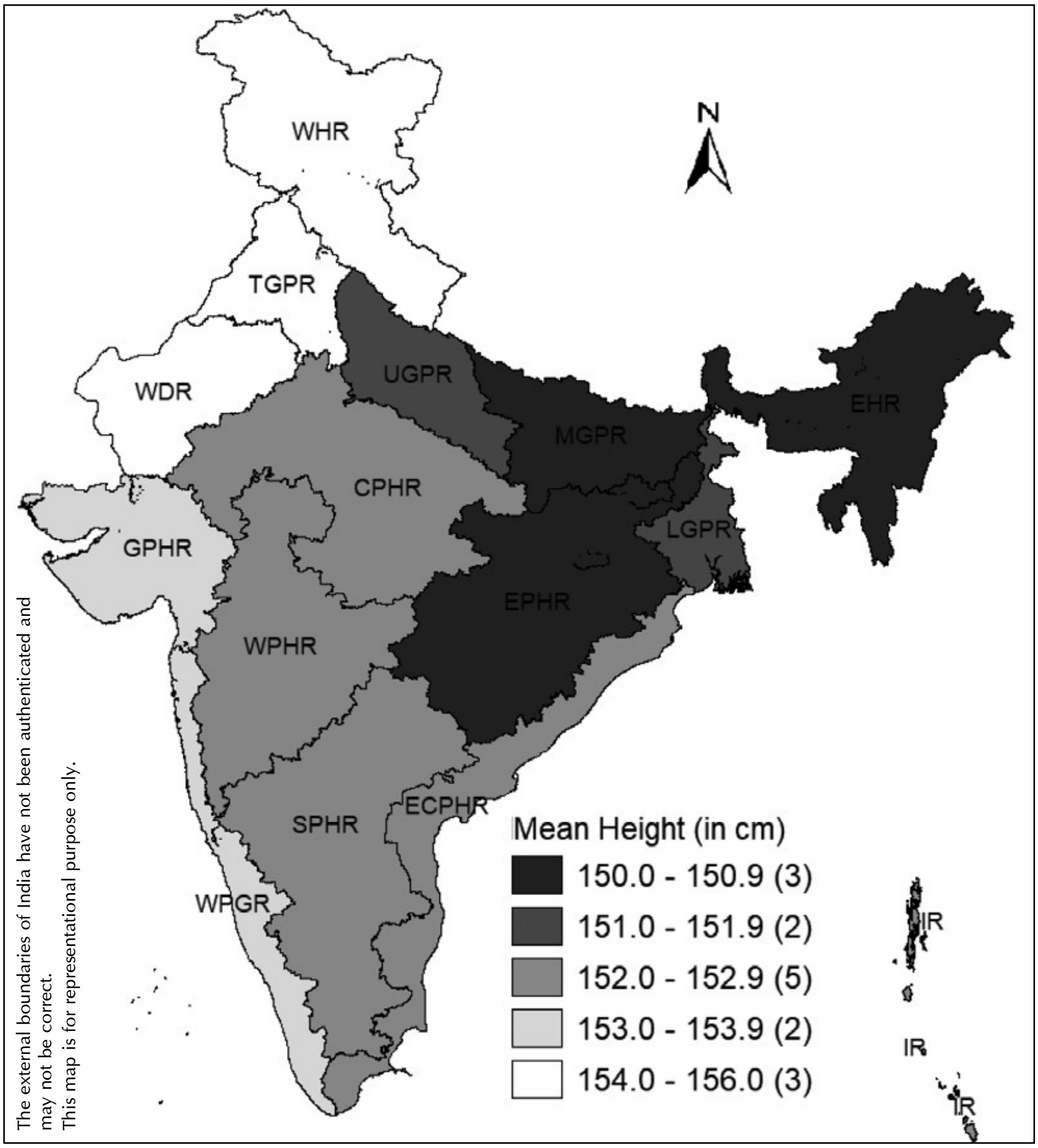


Table 2

Percentage Poor and Rich and sample size according to Agro Climatic regions, 2015-2016

Agro climatic zones	Household Wealth Index (%)			Sample size	
	Poor (first and second quintiles)	Middle (third quintile)	Rich (fourth and fifth quintiles)	Women 20-29 years	Men 25-34 years
WHR	21.4	24.1	54.5	17140	2762
EHR	58.6	20.9	20.4	32031	3783
LGPR	49.8	20.3	29.9	4585	540
MGPR	71.5	14.0	14.6	24937	2317
UGPR	49.3	16.5	34.3	21683	2407
TGPR	7.1	15.4	77.6	17376	2300
EPHR	65.1	14.4	20.5	28615	3315
CPHR	52.3	17.1	30.6	23353	2854
WPHR	33.9	22.0	44.1	14874	1979
SPHR	24.5	27.3	48.1	14934	2104
ECPHR	28.0	26.1	46.0	8482	1030
WPGR	9.2	17.7	73.2	6226	1097
GPHR	25.2	20.2	54.5	7982	1788
WDR	36.7	23.0	40.4	4447	476
IR	14.0	20.1	66.0	1164	168
Total				227829	28920

Figure 3

Mean height of adults by poverty and Agro- climatic zones, 2015 - 2016

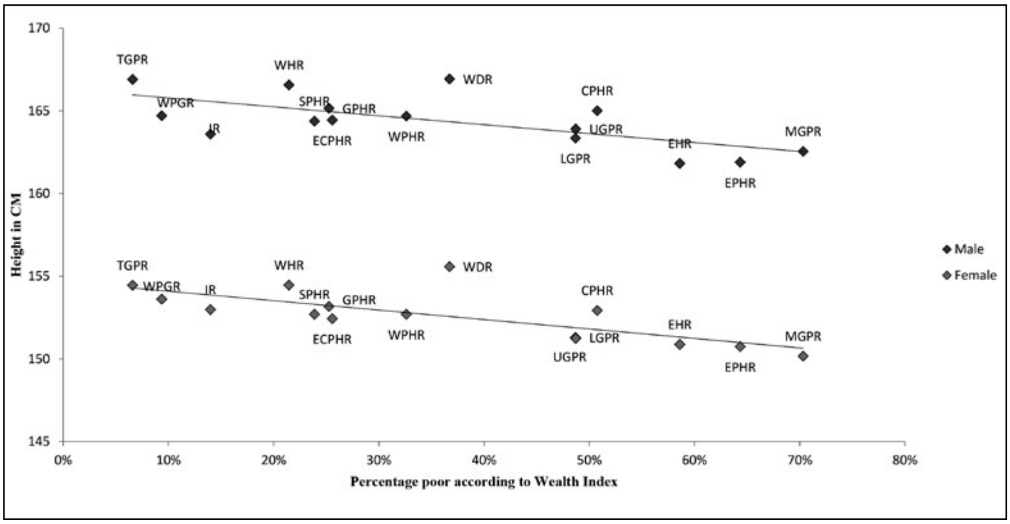


FIGURE 4

Mean height of adults by percentage poor in the Districts of India, 2015 - 2016

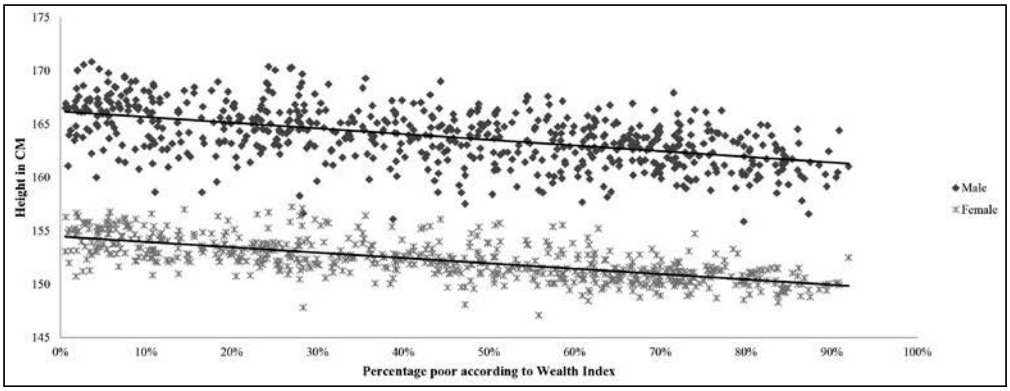


TABLE 3

Mean height of women aged 20 – 29, and men aged 25 - 34 years according to wealth index and Agro-climatic regions, 2015 – 2016

Agro climatic zones	Mean height of women		t-statistic	Mean height of men		t-statistic
	Poor	Rich		Poor	rich	
WHR	153.60	154.93	-9.93*	165.09	167.40	-6.62*
EHR	150.09	152.72	-32.10*	160.72	163.92	-11.14*
LGPR	150.58	152.63	-10.21*	161.83	165.47	-4.81*
MGPR	149.42	151.95	-25.36*	161.43	164.63	-9.06*
UGPR	150.04	152.39	-26.12*	162.46	165.42	-9.42*
TGPR	153.18	154.77	-9.44*	165.29	167.00	-3.73*
EPHR	150.07	152.37	-28.32*	160.87	163.94	-12.67*
CPHR	151.96	153.96	-22.70*	163.36	166.28	-9.54*
WPHR	151.79	153.33	-15.69*	162.99	165.60	-10.09*
SPHR	151.37	153.49	-16.45*	161.20	165.61	-9.98*
ECPHR	150.87	153.31	-16.37*	163.08	165.68	-3.76*
WPGR	150.51	154.32	-12.88*	163.88	164.63	-3.76*
GPHR	151.64	154.04	-14.96*	162.40	166.70	-8.84*
WDR	154.72	156.22	-7.64*	165.75	167.48	-2.70*
IR	151.46	153.55	-2.99*	160.97	165.14	-1.72

*P-value significant at 95% CI

Table 4

Consumption of at least two types of proteins daily and mean height by the consumption of protein of women aged 20 – 29 and men aged 25 - 34 years according to Agro-climatic regions, 2015 - 2016

Agro climatic zones	Percentage women consuming at least two types of protein daily	Mean height of women aged 20-29 years			Percentage men consuming at least two types of protein daily	Mean height of men aged 25-34 years		
		Women consuming less than two types of protein daily	Women consuming at least two type of protein daily	t-statistic		Men consuming less than two types of protein daily	Men consuming at least two type of protein daily	t-statistic
WHR	31.7	154.34	154.53	-2.78*	37.8	166.44	166.8	-0.36
EHR	24.0	150.67	151.54	-7.13*	22.1	161.5	162.99	-2.58*
LGPR	29.2	150.97	151.87	-4.26*	25.3	162.73	164.74	-3.58*
MGPR	32.2	149.78	150.89	-13.42*	32.9	162.09	163.5	-5.39*
UGPR	15.5	151.10	152.16	-8.93*	16.2	163.66	165.26	-3.81*
TGPR	27.6	154.26	155.07	-6.05*	33.4	166.56	167.35	-3.27*
EPHR	13.3	150.57	151.82	-13.24*	12.0	161.70	163.34	-5.43*
CPHR	16.2	152.81	153.35	-6.08*	20.8	164.51	166.24	-5.1*
WPHR	30.8	152.29	153.42	-8.12*	23.5	164.08	166.43	-3.25*
SPHR	46.1	152.45	152.96	-4.51*	45.1	163.86	164.51	-0.45
ECPHR	26.3	152.11	152.93	-6.33*	36.6	164.06	165.28	-3.14*
WPGR	41.7	153.40	153.91	-3.38*	40.9	164.53	164.92	-0.73
GPHR	31.7	152.88	153.81	-6.35*	27.6	165.12	165.55	-0.49
WDR	15.0	155.39	156.69	-5.4*	11.4	166.66	168.73	-2.1*
IR	26.1	152.77	153.56	-0.24	24.3	163.47	164.28	-0.06

*P-value significant at 95% CI

Table 5

Linear regression analysis of mean height of women aged 20-29 years (District as unit of analysis)

	Unstandardized Coefficients	Std. Error	Standardized Coefficients	Sig.	95.0% Confidence Interval for B	
	B		Beta		Lower Bound	Upper Bound
(Constant)	155.247	0.204		0	154.847	155.648
Women consuming at least 2 proteins	-0.009	0.004	-0.078	0.014	-0.016	-0.002
Agro-climatic regions*						
Percentage Poor	-0.028	0.003	-0.379	<0.001	-0.033	-0.022
EHR	-2.388	0.19	-0.437	<0.001	-2.761	-2.016
LGPR	-2.312	0.32	-0.183	<0.001	-2.941	-1.682
MGPR	-2.925	0.223	-0.460	<0.001	-3.364	-2.487
UGPR	-2.397	0.228	-0.317	<0.001	-2.845	-1.949
TGPR	-0.122	0.207	-0.018	0.555	-0.528	0.284
EPHR	-2.625	0.219	-0.439	<0.001	-3.056	-2.194
CPHR	-0.886	0.213	-0.136	<0.001	-1.304	-0.468
WPHR	-1.27	0.213	-0.172	<0.001	-1.69	-0.851
SPHR	-1.337	0.208	-0.197	<0.001	-1.746	-0.929
ECPHR	-2.021	0.244	-0.223	<0.001	-2.5	-1.542
WPGR	-0.315	0.252	-0.034	0.212	-0.809	0.18
GPHR	-1.218	0.239	-0.137	<0.001	-1.686	-0.749
WDR	1.449	0.384	0.092	<0.001	0.694	2.204
IR	-1.186	0.548	-0.051	0.031	-2.263	-0.11

*WHR – Reference category; R Square and Adjusted R Square: 0.685, 0.676

Table 6

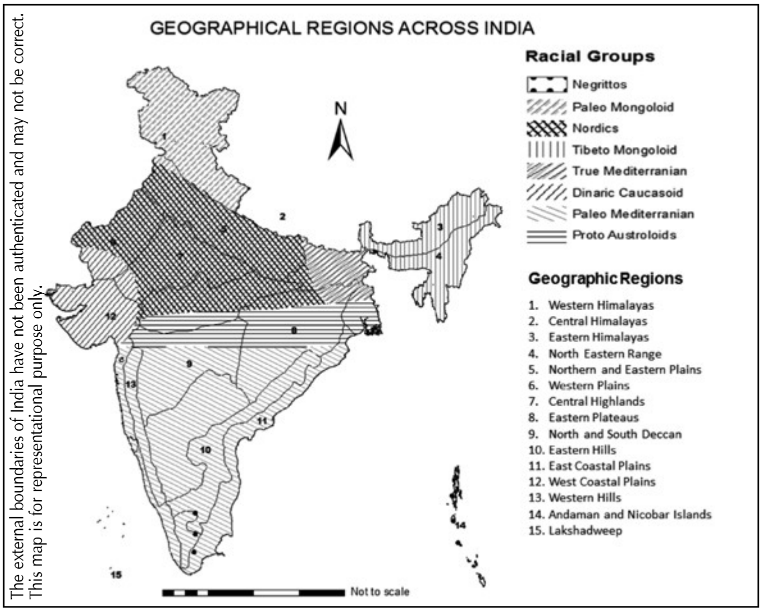
Linear regression analysis of mean height of men aged 25-34 years (district as unit of analysis)

	Unstandardized Coefficients	Std. Error	Standardized Coefficients	Sig.	95.0% Confidence Interval for B	
	B		Beta		Lower Bound	Upper Bound
(Constant)	167.194	0.363		<0.001	166.48	167.908
Men consuming at least 2 proteins	-0.035	0.005	-0.345	<0.001	-0.045	-0.026
Percentage Poor	-0.009	0.005	-0.063	0.104	-0.019	0.002
Agro-climatic regions*						
EHR	-3.711	0.351	-0.480	<0.001	-4.4	-3.021
LGPR	-2.019	0.589	-0.113	0.001	-3.176	-0.861
MGPR	-1.793	0.409	-0.199	<0.001	-2.595	-0.991
UGPR	-1.238	0.42	-0.116	0.003	-2.062	-0.413
TGPR	0.283	0.378	0.030	0.454	-0.459	1.025
EPHR	-3.018	0.405	-0.357	<0.001	-3.813	-2.223
CPHR	-0.484	0.389	-0.053	0.213	-1.248	0.279
WPHR	-0.997	0.396	-0.095	0.012	-1.774	-0.22
SPHR	-1.779	0.371	-0.185	<0.001	-2.509	-1.05
ECPHR	-1.595	0.446	-0.125	<0.001	-2.472	-0.719
WPGR	-0.824	0.46	-0.063	0.074	-1.727	0.08
GPHR	-1.454	0.441	-0.115	0.001	-2.32	-0.587
WDR	1.318	0.709	0.059	0.063	-0.074	2.71
IR	-2.983	1.008	-0.09	0.003	-4.962	-1.004

*WHR –Reference Category; R Square and Adjusted R Square: 0.469, 0.455

Figure 5

Climatic regions by racial groups (Adopted from climatic regions given by Chatterjee (1975) and presented in Majumder et al (1990) and racial classification from Guha (1935), Ali(2019))



Climatic regions by racial groups (Adopted from climatic regions given by Chatterjee (1975) and presented in Majumder et al (1990) and racial classification from Guha (1935), Ali(2019))

TABLE 7
Race and their sub-categories by location in India

Race	Sub –category/Tribe	Region/State
Negrito	Jarwawas, Onges, Sentinelese, Great Andemanese, Jaroya, Kadar	Andaman and Nicobar,
	Pullayans	Palni hills, Kerala and Tamil Nadu
	Kadors	Cochin, Kerala
	Badgis	Rajmahal hills, Jharkhand
	Angami Nagas	North East
Proto-Australoid	The Bhils, Kols, Badagas, Korwas, Kharwars, Mundas, Bhumjis and Malpaharis	Chottanagpur region, Central India
	Chenchus, the Kurumbas, the Yeruvas and the Badagas	Southern India
Mongoloid	Palaeo-Mongoloid	Fringes of Himalayas in Assam and Myanmar border
	Tibeto- Mongoloid	Sikkim, north-western Himalayas and Trans Himalayan regions, Ladhak
Dravidian	Gondis	Madhya Pradesh, Maharashtra, Chattisgarh, Uttar Pradesh, Telangan, Andhra Pradesh, Bihar, Odisha
	Chencu	Andhra Pradesh, Telangana, Odisha
	Kurukh	Chhattisgarh, Jharkhand and Odisha
	Badagas, Irula	Tamil Nadu
	Kannadigas, Kodavas	Mainly in Karnataka
	Malayalis	Kerala, Lakshadweep
Mediterranean	Palaeo-Mediterranean	North India, Tamil and Telugu Brahmins
	Mediterranean	Lower caste of north India
	Oriental-Mediterranean	Rajasthan and Western Uttar Pradesh
Brachycephals	Alpinoids, Dinaric, Armenoids	Bonias of Gujarat, Kayastha caste of Bengal Khatiawar – Gujarat, Coorgis and Parsis -, Karnataka, Maharashtra and Tamil Nadu
Nordic or Indo-Aryan		Punjab, Rajasthan and Jammu

Source: Adopted from Guha(1935), Ali (2019),
https://www.yourarticlelibrary.com/population/population-of-major-racial-groups-in-india/19834; https://www.jagranjosh.com/general-knowledge/racial-groups-of-india-1448688039-1

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