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HEIGHT IN RELATION TO MACRONUTRIENT CONSUMPTION AND SELECTED SOCIOECONOMIC PARAMETERS AMONG LIMBU AND MECH ADOLESCENTS FROM DARJEELING AND JALPAIGURI DISTRICTS IN WEST BENGAL, INDIA

ABSTRACT: Height of a population is affected by both genetic and environmental factors including nutrition and socioeconomic background. Dietary habits, patterns and quality of food consumptions depend on socioeconomic condition. Prevalence of low height-for-age or stunting is high in low and middle-income countries. The aim of the present study was to identify the association of height with macronutrients in diet (protein, lipid, carbohydrate) and selected household socioeconomic factors in 16 to18-year-old boys and girls of Limbu and Mech communities from Darjeeling and Jalpaiguri districts in West Bengal, India. The study was cross-sectional. Principal Component Analysis (PCA) was used to draw meaningful interpretation of the association between socioeconomic variables and height of 335 adolescents of Limbu (75 boys, 89 girls) and Mech (77 boys, 94 girls) communities. Socioeconomic parameters such as monthly household per capita income and expenditure (MHPCIE) and household characteristics (HC) were two extracted components by PCA. The PCA exhibited 70.96% variance of data on socioeconomic parameters, explained by MHPCIE and HC among other components. A linear regression model was used to observe the interrelationships between macronutrients in diet (consumption rates of protein, lipid, and carbohydrate) and selected socioeconomic parameters (MHPCIE, HC, and mother's occupation) with height. Results showed height significantly varied in boys and girls from two communities. Macronutrient consumption rates and HC did not show significant interrelationships with height. However, height had significant association with MHPCIE and mother's occupation (housewife versus working mother). In conclusion, the present study revealed that socioeconomic factors had more association with height than macronutrient consumptions in diet. Height of the participants from the households with higher MHPCIE were taller than others. Children of working mothers were taller than those of housewife mothers.

KEY WORDS: Height – Macronutrients – Household characteristics – Income and expenditure – Mother's occupation

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INTRODUCTION

Adolescence is a transition period in which rapid physical growth, sexual maturity and psychological changes take place. Growth of an individual mostly depends on the interaction between genetic and environmental factors (Hill, Byrne 2010). Different factors such as birth weight, parental height, nutrition, physical activities and socioeconomic parameters affect human growth (Tanner 1990). Based on an empirical analysis of 56 studies on height from 20 countries, Steckel (1983) found a nonlinear relation between average height and per capita income and showed that income distribution affects average height.

Boys and girls reach approximately 95% of adult height during middle and late adolescence ranging between 14 and 19 years of age (Datta Banik *et al.* 2017, Sawyer *et al.* 2018). Sexual maturity and psychosocial development are other characteristics of this stage (Casey *et al.* 2010). Height also has genetic predisposition. It is often found that a short statured parent has short statured children. If a population has short statured adults, usually they have history of long term nutritional stress, which depends on their food consumptions, quality of life and socioeconomic factors (Hill, Byrne 2010). Association of maternal short stature with stunting (low height-for-age) in Mexican children has been reported earlier (Hernandez-Diaz *et al.* 1999). A cross-sectional survey from Yucatan in Mexico reported that Maya mother's height <150 cm and child's birth weight <3000 grams both were significant predictors of stunting in children (Azcorra *et al.* 2016, Varela-Silva *et al.* 2009, 2010).

One of the common causes of growth retardation is poverty related malnutrition. Poverty is always associated with poor dietary habits, improper hygiene and sanitation which spread infections and lead to stunting in children (McGregor *et al.* 2007). An overall trend of retardation of growth and maturation in Yucatan populations from Mexico in last two centuries were reported (Siniarska, Wolanski 1999). Maya communities of Yucatan with dietary habits resulted in both short stature and thinness. Since European colonial period, Maya diets were combined with marginalization, heavy workloads and recurrent respiratory and gastrointestinal infections. In addition, periodic epidemics of measles reduced nutrients available for body growth (Bogin 2013).

Human beings need a wide range of food to lead a healthy life and diets that should be planned, based on sound nutritional principles (Gopalan *et al.* 1996). Adequate amount of food intake, together with proper selection of quality food (for example, fruits, vegetables and no processed etc.) leading to balanced diet are required to maintain good health. Adolescence is also considered to be a vulnerable period of nutrient demand due to faster increase in physical growth and development. Lifestyle and food habits change in this age affect nutrient intakes and needs. Some may have an extra demand of food due to different factors such as high rate of physical activity, chronic diseases, excessive dieting or addiction of alcohol or drug (Spear 2002).

Both dietary habits and food preference in children depend on food intake pattern in a household environment. Different factors influence diet in a very complex and interactive way. Family members have an important role in determining food habits in children. In addition, food habits of children and adolescents are also influenced by their school environment, media and other social interactions (Serra-Majem *et al.* 2009). When they grow up, children independently develop their food habits and lifestyle (Birch, Fisher, 1998). In a study from Hail region of Saudi Arabia, it was found that mean protein, calcium and potassium intake rates were significantly low in stunted children compared to the normally growing children and adolescents (Alshammari *et al.* 2017). Self-induced restricted nutrient intake delayed pubertal growth in suburban upper-middle and upper-class children and adolescents in the U.S.A (Rogol *et al.* 2002). Socioeconomic factors are more important because other factors like nutritional status, quality food and household environment depend on socioeconomic status of parents and other earning members. Using the principal component analysis (PCA), Leone *et al.* (2010) observed three types of dietary patterns among 5 to17 year-old school-going Scottish children: "healthier", "unhealthy" and "snacks and pudding". The healthier pattern was characterized by larger consumption of fruits and vegetables; this pattern was observed in people who had higher income and education, whereas the two other patterns were observed in lower socioeconomic groups of people who had lower education level.

Social scientists are always interested to find out the underlying socioeconomic factors influencing height across the population and changes of height within the population (Steckel 1983, 1995, WHO 2018). Height of a population was correlated with earning in the labour market (Case, Paxson 2008). In developing countries, chronic undernutrition like height deficit decreased significantly from 32.8% to 6.8% by 2006 due to economic growth, which improved socioeconomic status such as family income, mother's education, maternal and child health care, water supply and sanitation (Cunha *et al.* 2017). In a study from Czech Republic, Bobak *et al.* (1994) found mother's education was significantly associated with height of children when they controlled other indicators such as birth weight and parental height. In a study among children from U.S.A., it was observed that socioeconomic factors such as education, occupation, family income and social structure such as socially mediated etiologic mechanisms of diseases during adolescence had long-term effects (Dufour *et al.* 2011). Mother's education and occupation were good indicators for health in children. Low socioeconomic status was associated with low weight and shorter height in childhood and adolescents in all cohorts in a longitudinal and observational study of high-income countries (Bann *et al.* 2018). According to the WHO report (2006), prevalence of stunting in school age adolescents from urban Calcutta (now Kolkata) was lower (12%) than the peers from urban slum in Mumbai (32%). Prevalence of stunting was very high (>39%) in Bangladesh, Nepal and Myanmar (WHO 2006).

Venkaiah and colleagues (2002) found that despite high prevalence of stunting, energy intake of 70% adolescents in India had more than 70% of "recommended dietary allowance" (RDA) for energy. Cereal intake was adequate, and protein and lipid intake rates were better though micronutrient intake was insufficient, as revealed by 24-hour recall method. However, the study observed the frequency of stunting to be higher among those who had mud houses and were from low-income families. On the other hand, stunting decreased with size of increasing land holdings and increasing per capita family income. Bhasin and Jain (2007) observed that there was low intake of healthy and protective foods in different tribal communities from Rajasthan in India. Cereals were staple food of those communities, but cereal intake was too low among them with other foods like pulses, animal protein, vegetables with reference to the RDA. The authors found prevalence of malnutrition was alarming as they conducted a nutritional survey using 24-hour recall method. Deaton and Dreze (2009) observed that there was a trend of declining food and calorie intake in India during last 25 years. According to them, this decline did not occur due to real per capita income or increase of food price for long time. It has occurred across the population due to unequal distribution of per capita expenditure.

The tribal communities in India historically suffered from nutrition and health hazards due to social and economic discrimination and marginalization. The forest policies during colonial period led to the displacement of tribal groups from their lands and they continued to remain marginalized in post-independent India (Gough 1974, Stokes 1978, Verghese 2016). Limbu and Mech are two Tibeto-Burman language speaking tribal communities who have some similarities in their ethnic origins (Bhattacharjee 2015). They live in the similar environmental conditions of eastern and some parts of north-eastern Himalayan and Sub-Himalayan regions of India. Like other tribal communities, they also have suffered from social and economic discriminations and policies of the State, although many Limbu people serve the country in the army over decades. Due to poverty, landlessness and nutritional stress, there is child growth failure in these populations (Bhattacharjee 2015). In recent years, government policies in education and occupation have sought to give better quality life to the tribal communities. Some nutritional intervention programs have helped them, but they are still suffering from poor nutritional status and chronic malnutrition. For example, Datta Banik *et al.* (2016) reported that there were more than 42% stunted children and adolescents in Limbu and Mech communities.

In this background, the aim of the present study was to investigate the interrelationships among height, consumption of macronutrients in diet and selected socioeconomic factors of 16 to 18-year-old boys and girls from Limbu and Mech communities.

PARTICIPANTS AND METHODS

The study was cross-sectional in nature. The sample comprised 16 to 18-year-old 335 adolescents (Limbu:75 boys, 89 girls), (Mech: 77 boys, 94 girls) from Darjeeling and Jalpaiguri districts of West Bengal, India.

Sampling design

Field work and data collection were done from June 2010 to September 2012. The Limbu and Mech community people mostly reside at hilly and Sub-Himalayan regions (foothills) of "*Tarai*" in Darjeeling district, and "*Dooars*" in Jalpaiguri and Alipurduar districts of West Bengal. Previously Alipurduar district was a sub-divisional town of Jalpaiguri district. From

2014, Alipurduar has been declared as a separate district in West Bengal. The Limbus are mostly indigenous people from hilly regions of eastern Nepal, between Arun and Mechi rivers. They also migrated from Tibet, Bhutan and Sikkim.

The villages were selected based on the information of the Census of India, 2011 but due to the unavailability of data of adolescents, representing ethnic groups, a random sampling technique was followed. The study area consisted of 102 Limbu and 28 Mech settlements (villages and hamlets) in Darjeeling and 31 villages from Jalpaiguri district (and part of the Alipurduar district at present) of West Bengal. From each selected village, the households having adolescents aged 16 to18 years were identified. The official documents issued by the Government of India, confirming the scheduled tribe identity for each participant was checked. Details of sampling procedure were mentioned in our previous reports (Bhattacharjee 2015, Datta Banik *et al.* 2016).

The Limbu villages were mostly located in Darjeeling, Kurseong, Kalimpong (presently a separate district) and Siliguri sub-divisions near Naxalbari, Bagdogra and Matigara blocks. The "block" is an administrative division in rural areas of a district. Mech settlements were also found in Naxalbari, Bagdogra, and Matigara regions of Darjeeling district. Limbu and Mech settlements were mostly found in Madarihat, Birpara and Falakata blocks of Alipurduar. The participants of the present study were healthy and did not suffer from any chronic diseases at least within three months before the study. Age of the participants was recorded from their birth certificate, school register and immunization card. Decimal age was calculated.

Ethical clearance

Institutional ethical committee approved the research work as a project for doctoral thesis of the lead author of this paper. Clearance was also obtained from the authorities of the Government of West Bengal, India. To reach community people, permission was taken from the locally elected representative body (*Gram Panchayat*). Moreover, to take information and measurements from the participants, informed consent was taken from their parents and school authorities. The participants gave their verbal assents.

Data collection

The study followed standard protocols to record anthropometric measurements (Lohman *et al.* 1988, WHO 1995). Height of the participants was measured in the morning between 7 and 9 A.M. Stunting was evaluated by low height-for-age Z-scores (HAZ) (de Onis *et al.* 2007, WHO 2007). The information on dietary habits and socioeconomic backgrounds were collected through interview using a pre-validated questionnaire from the participants and their parents during household visits.

Recording and evaluation of dietary habits and macronutrient consumption rates

Dietary habits of the participants were evaluated using a list of specific food items that were locally available. Diet survey was carried out with the help of a questionnaire to note the food list (Bhattacharjee 2015); a 24-hour recall method was used (three different days in a week, including Monday to include the meals consumed in the weekend) to record the approximate individual consumption of main food items and accordingly an estimate of monthly consumption of different food items by the household members was done. The consumption rates (gram per day) of macronutrients (protein, lipid and carbohydrate) were estimated. The average consumption of different macronutrients was also calculated from monthly intake rates of the food items in the household. In this calculation, to begin with, monthly individual food intake was calculated. Then monthly consumptions were divided by 30, which was an average intake (gram per day). To determine individual consumption of different macronutrient components in diet (protein, lipid, carbohydrate), the study looked for the distribution of both adults and children by age groups and sex in the household. Following Gopalan *et al.* (1996), consumption unit for each household member was determined with respect to the Indian population and then total household consumption units were determined.

Socioeconomic backgrounds

The socioeconomic status (SES) of a household was evaluated using per capita income, per capita expenditure as well as some other household characteristics. Household per capita income and expenditure (in Indian rupees with symbol of INR ₹) were continuous variables. The currency conversion rate at the time of interview was 1 $ U.S.A = ₹ 65. The house type was classified, based on wall and roof characteristics as follows: (i) not concrete (mud walls with thatched roof), (ii) semi concrete (brick walls with thatched roof), (iii) concrete (brick walls with concrete or tiled roof). Houses were also categorized by the presence or absence of toilet inside the house and water use as follows: (i) common source of water (pond, stream, well, and tube-well) (ii) well and (iii) piped water in the household territory. Therefore, house type and water use were categorical and dummy variables were created to use in the principal component analysis (PCA). The other household characteristics included availability of electricity connection, land ownership, cattle ownership (goat and/or sheep ownership, pig farm), and household goods (cycle, refrigerators, television, mobile phone). Mother's occupation was binomial: housewife (1) and working mother (0).

Data analysis

Data analysis was done using the Statistical Package for the Social Sciences (SPSS, version 15.00). Descriptive statistics including mean and standard deviation values of variables at 95% confidence interval levels were calculated. To estimate the significant differences in mean values of the variables in boys and girls from Limbu and Mech communities, Student's t-test has been used.

The PCA was run to produce a small number of linear combinations among the correlated variables, which accounted for most of the data variability and to improve the interpretations of the relationships between variables that were being considered. Several proxy indicators of SES were taken into the consideration for the PCA and finally two components were extracted: household characteristics (Component 1) and monthly household per capita income and expenditure (Component 2). Different household characteristics included house type, toilet in house, and water use, as described before. Other household characteristics used in PCA including available electricity connection, land ownership, cattle ownership and household goods showed very low variance and didn't have significant influence on height in separate analysis and were subsequently dropped from the PCA.

Multiple linear regression analysis was done to interpret the interrelationships between height of the participants and several predictors including participant's age and sex, ethnic background, macronutrient (protein, lipid, carbohydrate) consumption rates (g/day), and selected SES parameters like household characteristics (Component 1), monthly household per capita income and expenditure (Component 2) and mother's occupation. A *p*-value <0.05 was considered statistically significant.

RESULTS

Mean and standard deviation values of age, height, height-for-age Z-score (HAZ) and consumption rates (gram per day) of macronutrients in diet (protein, lipid and carbohydrate) of boys and girls from Limbu and Mech communities are presented in *Table 1*. Significant sex difference (using Student's t-test) ($p < 0.05$) was observed in mean values of height, protein and carbohydrate consumption rates (g/day) in Limbu and Mech boys and girls. Mean values of lipid consumption (g/day) also showed significant sex difference in Mech community. Limbu boys had higher intake rates of macronutrients than Limbu girls; whereas Mech girls had higher intake of macronutrients than boys from the same community. Significant sex difference was not observed in mean values of HAZ among Limbu and Mech participants. Significant differences ($p < 0.05$) in mean height, HAZ, macronutrient consumption rates (g/day) have been found between the communities by sex. Mech boys and girls were taller than peers from Limbu community. However, Limbu participants showed higher consumption rates of macronutrients than Mech boys and girls. Frequency of stunting (not presented in a separate table) in the present study was remarkable: Limbu (boys 42.7%, girls 39.3%) and Mech (boys 16.9%, girls 21.3%). The overall prevalence of stunting in the sample was more than 30%.

Socioeconomic status

Mean household per capita monthly income among Limbu boys and girls were ₹ 4,405.56 and ₹ 4108.61, respectively. The mean values of monthly per capita income in the households of Mech boys and girls were ₹ 4,853 and ₹ 4423. The mean values of household per capita monthly expenditure of Limbu boys and girls were ₹ 3,929 and ₹ 3,729 respectively whereas monthly household per capita expenditure among Mech boys and girls were ₹ 3,636 and ₹ 3,363. In Limbu community, the proportion of working mothers was 75%. It was 73% in the Mech community.

Principal Component Analysis

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.66) and Bartlett's test of sphericity ($\chi^2 = 1294.28$, $p < 0.05$) indicated a strong interrelationship between variables. The two extracted components had eigenvalues ≥1.0 (Scree Plot, Figure 1) and they accounted for 70.96% variation of SES data in this study. The PC1 explained 44.35% variation

TABLE 1: Descriptive statistics of age, height, height for age Z-scores, and macronutrient consumption rates (g/day). SD: Standard deviation. #Height-for-age Z-scores; *g/day.

Variables	Limbu		Mech		Limbu (boys vs girls)		Mech (boys vs girls)		Community (Limbu vs Mech boys)		Community (Limbu vs Mech girls)	
	Boys	Girls	Boys	Girls								
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	t	p-value	t	p-value	t	p-value	t	p-value
Age (years)	17.06 (0.98)	17.16 (1.04)	16.94 (0.88)	17.10 (0.95)	0.63	0.53	1.14	0.25	0.82	0.41	0.43	0.67
Height (cm)	159.05 (5.78)	149.37 (4.63)	163.69 (8.70)	152.95 (5.46)	11.91	**<0.001**	9.85	**<0.001**	3.87	**<0.001**	4.77	**<0.001**
HAZ#	-1.89 (0.79)	-1.94 (0.74)	-1.27 (1.22)	-1.39 (0.85)	0.46	0.65	0.77	0.44	3.71	**<0.001**	-4.70	**<0.001**
Protein consumption*	47.24 (9.08)	43.50 (8.36)	23.36 (4.42)	30.49 (6.84)	2.75	**<0.01**	7.89	**<0.001**	20.69	**<0.001**	11.51	**<0.001**
Lipid consumption*	24.17 (3.70)	23.12 (3.57)	14.85 (3.18)	20.36 (6.03)	1.86	0.06	7.23	**<0.001**	16.69	**<0.001**	3.73	**<0.001**
Carbohydrate consumption*	264.95 (47.31)	245.83 (40.82)	204.61 (30.95)	262.87 (54.07)	2.78	**<0.01**	8.38	**<0.001**	9.33	**<0.001**	2.39	**0.02**

of SES in the study. The factors extracted after varimax rotation, the resulting component equations were:

Household characteristics (PC1): − 0.880*house type dummy1 − 0.806*water use dummy1 + 0.804*toilet in the house + 0.779*house type dummy 2 + 0.624*water use dummy2 + 0.105*monthly per capita family income − 0.062*monthly per capita household expenditure.

Household per capita income and expenditure (PC2): − 0.132*house type dummy1 + 0.012*water use dummy1 + 0.169*toilet in the house + 0.002*house type dummy2 − 0.117*water use dummy2 + 0.953*monthly per capita household income + 0.950*monthly per capita household expenditure.

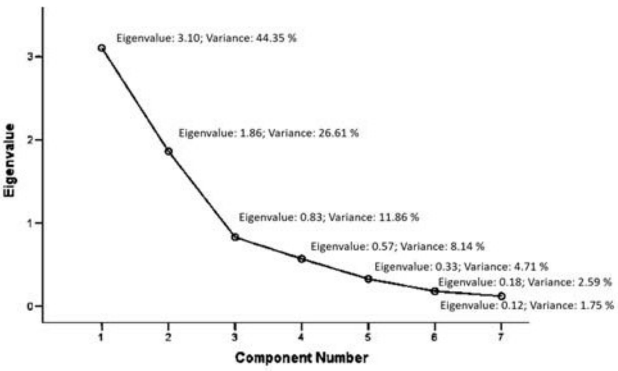

FIGURE 1: Scree plot Height Macronutrients SES Limbu Mech (1).

Regression model

The multiple linear regression model was used to show how height was related to age (years), sex (boys and girls), community (Limbu and Mech), macronutrient consumption rates and different socioeconomic parameters including two extracted principal components (household characteristics, household income and expenditure) and mother's occupation. Parameter estimation of response variable height included 95% confidence interval for regression coefficients of the predictors. In the model, ANOVA p-value was < 0.05, indicating statistically significant interrelationships between variables at the 95.0% confidence level.

Height as a response variable showed 49.0% of variability in the fitted model as explained by the R-squared statistic. Height was significantly related to sex, community, monthly household per capita income and expenditure and mother's occupation. Age, household characteristics, macronutrient intake rates had no significant interrelationships with height (Table 2). Height showed positive interrelationship with monthly household per capita income and expenditure as 1.11 cm height increase with one unit increase of per capita income and expenditure in a household. The children of housewife mothers were shorter in height than those of working mothers. Approximately 2.06 cm. lower height has been observed among adolescent boys and girls of housewife mothers than those of working mothers.

The model including height as a response variable produced the equation:

Height = 142.03 + 0.44*Age + 9.73*Sex + 4.20*Community + 0.05*Protein consumptions −0.09*Lipid consumptions + 0.00*Carbohydrate consumption + 0.37* Household characteristics + 1.11*Monthly household per capita income and expenditure − 2.06*Mother's occupation.

DISCUSSION

The present study revealed high prevalence of stunting (>30%) among 16 to 18-year-old adolescent boys and girls from Limbu and Mech communities from Darjeeling and Jalpaiguri districts in West Bengal. The study also showed similar patterns of results reported by several Indian and international studies. Stunting continues to be a major health challenge in India. In a study based on nationally representative data of adolescents from nine states of rural India, Venkaiah *et al.* (2002) reported that 39% adolescent boys and girls were stunted. The rate of stunting increased from 34.7% to 59.7% in boys with increasing age from 10 years to 17 years. Among girls, prevalence of stunting increased from 32.5% to 46.7% from early adolescents up to 13 years of age, then it decreased to 37.2% at the age of 17 years. A recent study of IFPRI (2018) found the rate of stunting (38.4%) in children from India and reported large variation of stunting across different districts (from as low as 12.4% to as high as 65.1%). According to UNICEF (2017), India has the highest number of adolescent (age group 10 to19 years) population in the world and adolescents constitute one-fifth of the Indian population. Many adolescent girls aged 15 to19 years were at high risk of early marriage and pregnancy with poor nutrition, unhygienic health conditions and domestic violence. Babies of those adolescent mothers also suffered from low birth weight with heightened risk of stunting.

The results of height-for-age of Limbu and Mech boys and girls had been compared with Indian Council of Medical Research (ICMR 2009) data in our previous publication (Datta Banik *et al.* 2016); results were based on the same research project. In the study among 6 to 18-year-old 1523 children and adolescents from Limbu (377 boys, 379 girls) and Mech (365 boys, 402 girls) communities, normalized data of height-for-age using LMS method was compared with growth

TABLE 2: Interrelationships between height (cm) and age (years) sex, community, macronutrient consumption rates, and selected socioeconomic parameters. SE= Standard Error. Sex (boys = 1, girls = 0); community (Mech = 1, Limbu = 0); Mother's occupation (Housewife = 1, working = 0). PC: Principal component.

Predictors	Regression coefficients		t	p-value	95% Confidence Interval for B	
	Beta	SE			Lower Bound	Upper Bound
Constant	142.03	6.52	21.79	0.00	129.21	154.85
Age (years)	0.44	0.35	1.26	0.21	-0.25	1.13
Sex	9.73	0.71	13.68	**<0.001**	8.33	11.13
Community	4.20	1.79	2.34	**0.02**	0.67	7.73
Protein consumption (g/day)	0.05	0.10	0.49	0.62	-0.15	0.25
Fat consumption (g/day)	-0.09	0.12	-0.70	0.48	-0.33	0.16
Carbohydrate consumption (g/day)	0.00	0.02	0.06	0.95	-0.03	0.03
Household characteristics (PC 1)	0.37	0.49	0.77	0.44	-0.59	1.34
Monthly per capita household income and expenditure (PC 2)	1.11	0.34	3.25	**<0.001**	0.44	1.79
Mother's occupation	-2.06	0.76	-2.70	**<0.01**	-3.57	-0.56

reference data of WHO and ICMR. The study showed median height of the Mech and Limbu boys and girls consistently below the standard median height-for-age reference curves of WHO but Limbu and Mech children and adolescents were taller than the corresponding values of height-for-age in the reference curve of ICMR. The ICMR data represented children from 16 States of rural India.

There was no available growth reference data from the region to compare with height-for-age data of Limbu and Mech boys and girls. However, there are few available reports on height-for-age of adolescents from neighbouring communities (Rajbanshi, Muslims, Hindu castes) in Darjeeling, West Bengal, India. A study (Mondal, Sen 2010) observed high prevalence of stunting and thinness among 10 to 17-year-old adolescents in Darjeeling district of West Bengal. The frequency of stunting was 43.1% among boys and 50.3% among girls; the values were higher than the estimated frequencies of stunting among Limbu (boys 42.7%, girls 39.3%) and Mech (boys 16.9%, girls 21.3%) participants. Another study from northern West Bengal (Roy *et al.* 2016) reported high prevalence of stunting (39.6%) among 9 to 18-year-old Rajbanshi girls.

In our study, linear regression model showed height was significantly related to the some of the predictors among 16 to 18-year-old Limbu and Mech adolescent boys and girls. Age had no significant effect on height in this age group of boys and girls from two communities. This might be explained in the light that during middle to late adolescence, boys and girls reach approximately 95% of adult height. A study from Merida, Mexico also reported similar trend where girls reached their estimated adult height earlier than boys in late adolescence (Datta Banik *et al.* 2017).

The present study also revealed carbohydrate and protein consumption rates (g/day) were very poor in these two study communities when comparing with recommended dietary allowances (RDA) of ICMR (2009) (Gopalan *et al.* 1996). Protein consumption was about 31% and 53% less among the participants from Limbu and Mech communities respectively than recommended protein allowances per day. The mean value of lipid consumption rate per day of the participants in the present study reached the standard allowances (22 g/day); still it was poor among the Mech boys (*Table 2*). According to the report of ICMR (2011), 70% to 80% dietary calories are derived from carbohydrate-enriched foods like cereals, millets, legumes and in a balanced diet, 50% to 60% energy is derived only from carbohydrate. This report also mentioned that recommended energy consumption rate for boys and girls of 16 to 18 years of age are 2640 kcal/day and 2060 kcal per day respectively. Therefore, daily requirement of carbohydrate intake is 280 to 360 g/day. However, mean values of carbohydrate intake rate by the participants of the present study was around 200 to 260 g/day. An earlier study revealed that vegetable and fruit consumption rates were very low compared to cereal intake in India (Venkaiah *et al.* 2002). However, no significant interrelationships were found in macronutrient consumption rates with height. Recording of macronutrient consumption rates using 24-hour recall method is insufficient to understand the dietary habit and nutritional status of a community because this method has some limitations but still it is very fast and cost effective to collect data from the community to understand overall dietary pattern, especially in a cross-sectional study (Thompson and Byers 1994). On the other hand, stunting cannot be explained by the present nutritional status and food consumption or nutrient intake in a day. It is a long-term effect in a population. Low height-for-age or stunting is an adaptive mechanism for chronic deficiency of food or nutrients when nutrient intake deficit runs for a long time in a community and body starts to balance the condition of deficiency and make the stature short, but weight-for-age remains normal. It is known as nutritional dwarfism (Mclaren, Read 1972, Stini 1975). The studies also stated that nutritional dwarfism was a separate category present when weight-for-height or weight-for-age was above 90% but height-for-age was below 90% of a standard reference.

From socioeconomic status (SES) information of 335 Limbu and Mech adolescents, it was observed that mean values of monthly household per capita income of Limbu and Mech households were 4,244 and 4,617 respectively. However, minimum income of the two communities were 2,167 and 1,750 respectively and the maximum household monthly per capita income were 10,000 and 30,000 respectively. Monthly household per capita income and expenditure (principal component 2) showed significant interrelationship with height. The study showed that adolescents were taller in the households where higher monthly household per capita income and expenditure were higher. Boys and girls of working mothers were also taller than those of housewife mothers. A possible explanation is working mother contributed more income to the family as mother's occupation was observed to be an important proxy indicator of household SES. A study observed higher SES, measured specially by income, literacy, and non-vegetarian diet were associated with nutritional status and played important roles in child growth (Bhandari *et al.* 2002). Height was strongly related to earning in the labour market as reported earlier (Case, Paxson 2008). In developing countries, malnutrition including height deficit in children and adolescents was related to poor economic growth (Cunha *et al.* 2017).

Limbu and Mech communities are indigenous of Darjeeling region. At present they live in the hilly and Sub-Himalayan regions in West Bengal. However, there is a history of migration of Limbu communities from some parts of eastern Nepal, Tibet, Bhutan and Sikkim. According to Chatterji (1951), Mech and Limbu communities share similar ethnohistory of origin. However, these communities differ in certain socioeconomic characteristics and other cultural attributes. We cannot explain how height growth and finally adult height show association with socioeconomic changes since supporting literature is not available. We found Mech community people had more areas of land for agriculture and Limbus were mostly engaged in business and government jobs, particularly in the army. A large section of Mech community is still engaged in their traditional occupation like pastoralism and farming.

Within the broad genetic frame of a community, height growth works in a very complex way. In recent development of auxological research on "As tall as my peers – similarity in body height between migrants and hosts" (Bogin *et al.* 2018), authors state that human social networks and competitive growth processes strengthen the concept of social connectedness that is involved in the regulation of human migrant growth. This study also reported that changes in living condition do not show equal effects on individuals. Therefore, optimum height of individuals in a community is regulated by social mechanism or adjustment of height may be the effect of non-genetic adjustment of "push and pull" factors of peers. In our study we could not test any effect of migration on differential height growth among Limbu and Mech adolescents. We could not establish the fact in the light of the new trend of auxological research (Bogin *et al.* 2018) why adolescent Mech boys and girls were taller than their Limbu peers. The present study revealed that there was no significant effect of macronutrient consumption rates on height in adolescents but socioeconomic factors including household characteristics, income and expenditure and mother's occupation had significant association with height.

CONCLUSION

The present study analyzed height and its relation to macronutrient consumption rates and selected proxy indicators of SES among 16 to 18-year-old adolescent boys and girls from two indigenous communities of West Bengal, India. As far as our knowledge goes, this is the first study of its kind from the region. Socioeconomic factors were found to play important roles in determining height of the adolescents. Macronutrient intake rates had no relation with height as stunting is chronic malnutrition and has a long-term effect. However, lack of data on the maturity of the participants was one of the shortcomings of the present study that should be considered in future. In summary, SES plays an important role in determining height among adolescents from two neighboring communities, considering ethnic differences and other involved biological and genetic factors. The prevalence of stunting observed in the sample of adolescents was remarkably high and calls for immediate intervention and public health nutrition policy measures to address child and adolescent health in this part of India. At a minimum, these efforts need to increase public awareness of the problem and to promote nutritional supplementation programmes by the government as well non-government agencies for healthy dietary habits and hygiene practices. School authorities and parents also need to be careful and participate in these programmes.

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CONFLICTS OF INTEREST

The authors had equal contributions to develop the manuscript and declare no conflict of interest.

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