Research Article

Anthropometric Characteristics of Underprivileged Adolescents: A Study from Urban Slums of India

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Purpose. The anthropometric status and growth of adolescents living in challenging conditions such as slums are insufficiently studied. The purpose here was to describe anthropometric characteristics and nutritional status of adolescents from urban slums of India and to study the factors affecting it. *Methods*. Anthropometric, socioeconomic and dietary habit data were collected using structured questionnaires of six hundred adolescents aged 10–19 years by house-to-house survey conducted in two randomly selected slums of Nashik, Western India. The growth of adolescents was compared using WHO and Indian reference populations. Mixed effects logistic regression models were used to examine associations between anthropometric measures and income, mother's education, household size, and dietary intake. *Results*. Prevalences of stunting and thinness were lower using the Indian reference population compared to that of WHO. Stunting was more prevalent than thinness in the study subjects, and boys suffered more than girls. The effect of age on stunting was different among boys than girls. A mother's education was highly significantly associated with both stunting and thinness in both sexes. Household size and income were significantly associated with the nutritional status of girls. *Conclusions*. Educating mothers about the nutritional needs of adolescents may help to improve adolescents' anthropometric profile and future health.

1. Introduction

Adolescence is a transitional phase between childhood and adulthood characterized by marked acceleration in growth [1, 2]. It is a second chance for growth or catch-up growth for those children who have experienced nutritional deficiencies in early childhood [3, 4]. A large number of adolescents from South and South-east Asian countries suffer from chronic malnutrition and anaemia which affect their development [1]. The high rate of malnutrition in girls contributes to the intergenerational cycle of malnutrition, and in most developing countries nutrition initiatives have focused on children and women, essentially neglecting adolescents, especially boys [1].

Anthropometry helps in assessing nutritional status and health risks among adolescents [5, 6]. Recommended measures for assessing nutritional status in school-aged children and adolescents are BMI-for-age and height-for-age [7]. Low BMI-for-age is classified as thinness and high BMI-for-age as overweight and obesity, and low height-for-age as stunting [7]. Stunting is a primary manifestation of malnutrition in early childhood and is an indicator of chronic undernutrition, while thinness indicates current malnutrition. Stunting increases the risk of morbidity, impairs cognitive development, and reduces work productivity in later life [8]. The consequences of undernutrition extend not only to later life, but also to future generations [9]. Both childhood obesity

and thinness are linked to underachievement in school and lower self-esteem [10]. Assessment of stunting and thinness is crucial for adolescents and a reference population is central to it. One of the objectives of the present paper is to compare estimates of malnutrition observed in this study population based on the growth reference curves developed for India [11] and the WHO Multicentre Growth Reference Study [12]. Several factors affect the nutritional status of adolescents. Among these, socioeconomic and demographic factors are associated with worldwide patterns of stunting and thinness [13].

India has a large population of adolescents (10–19 years of age, 21%) and also of slum dwellers in urban areas (15% of total urban population of India, [14, 15]). Although a number of studies from India have been published on adolescents' anthropometry among school children from urban and rural areas reporting prevalence of undernutrition ranging from 17% to 65% [16], there are only a few studies conducted on the growth of adolescents from urban slums covering adolescents not attending school (e.g., [17]). Addressing the growth issues of this underprivileged group could be an important step towards breaking the vicious cycle of intergenerational malnutrition, chronic diseases, and poverty. Such assessments need special consideration since they constitute a large proportion of the urban population and suffer from adverse living conditions such as unsafe water, poor housing, overcrowding, and limited health facilities, especially when compared to school-going urban adolescents not living in slums. The purpose here is to describe anthropometric characteristics and nutritional status of adolescents from urban slums of India and study the factors affecting it. In the current study, nutritional status as determined by height-for-age and BMI-for-age of a sample of adolescents from urban slums of Maharashtra with low per capita income is examined. Their status is also compared with the WHO and Indian reference populations by age and sex. Note that Maharashtra has the highest slum population as a proportion of urban population (27.3%) in India [15]. Further, factors such as mother's education, family income, and diet, known to affect the nutritional status (stunting and thinness) of school children, are examined for these adolescents. Girls have been the focus of nutritional research and growth-related issues stemming from a lack of proper nutrition. The novelty of the present work lies in examining whether the situation among boys differs from that of girls.

2. Methods

The study was undertaken over a six-month period from November 2010 to April 2011 in two urban slums in Nashik city in the state of Maharashtra, Western India. Out of the 32 notified slums by the Nashik Municipal Corporation (NMC) within the city limits, one slum was selected randomly. The slums were enumerated and a number between 1 and 32 was selected randomly. The slum with the selected number was chosen for the study. Similarly, out of 27 slums notified by the NMC on the outskirts of the city, one was selected by randomly choosing a number between 1 and 27.

After the selection of slums, a survey was carried out to gather background information on households, number of family members, and number of boys and girls between the age of 10–19 years from 539 (241 + 298) households. Written consent was also sought, at the same time. One of the selected slums had 1384 households (reported by the NMC) and the first 241 households interviewed, which gave the required number of adolescents for the study, were included. All 298 households from the other slum were included. All the households with at least one adolescent (200 out of 241 and 150 out of 298 households) and which gave consent to participate in the study were selected. This gave 156 (out of 200) and 120 (out of 150) households and 545 adolescents for the present study.

Data on household characteristics, socioeconomic indicators, and eating habits were collected using structured questionnaires by house-to-house survey. The adolescents whose parents gave consent were interviewed to collect data on their demographic and life style factors, habits, physical activity, diet, and so forth. The questionnaires were administered by two teams consisting of three trained surveyors each. Another team of five members carried out measurements. One member of the team collected data on weight, one on height, and the other three on blood pressure. The field study was approved by the Institutional Review Board of Tampere School of Health Sciences in 2010. The study was conducted in accordance with the ethical guidelines in the Helsinki Declaration of 1975, as revised in 2000.

In the present paper, the analysis of anthropometric data is restricted to the age group 10–18 years (boys = 257, girls = 261, total = 518) since the growth curves from India are available up to the age of 18 years.

2.1. Anthropometric Measurements. Data on height and weight were collected in the present study. The participants were invited to camps at scheduled times with their parent or guardian for the recording of anthropometric measurements. Height (in cm) was measured using a simple nonelastic measurement tape to the nearest integer. Weight (in kg) was recorded using a new bathroom scale (brand Libra, Model no. 770) to the nearest integer. Two readings each were taken for height and weight and the average was used for analyses here. Body mass index (BMI) was defined as the ratio of weight (in kg) to the square of height (in m).

2.2. Stunting and Thinness. Height-for-age and BMI-for-age Z-scores were derived using WHO as well as Indian reference populations [11, 12]. A subject was classified as stunted if the height-for-age score was below −2, as thin if BMI-for-age score was below −2, and overweight if BMI-for-age score was above 1 [18].

2.3. Independent Variables. In this study, it was examined whether differences in household per capita income, mother's education, household size, and dietary intake of protein/fat within the slum population were associated with variation in anthropometric status. The level of economic wellbeing is one of the basic factors of the household that is reflected in

child undernutrition. The poverty that children experience is associated with inadequate food, poor sanitation, and poor hygiene, which lead to increased infections, and is also associated with low maternal education, increased maternal stress, and depression [19–21]. Household characteristics such as mother's education, poverty, and household size are closely linked to aggregate anthropometric failure in India [22, 23]. Interestingly, a larger number of over-5-year-old children in a household have been found to be associated with *less* child anthropometric failure than if there were fewer children [23]. The role of household size in determining the nutritional status of children remains unclear. It is known that the mother's education is generally reflected in a child's wellbeing. Educated mothers could be more aware of health issues, with more means to get information than uneducated mothers [22]. Children of mothers with higher education tend to have better nutritional status [19, 23]. The mother's education level here was grouped into two categories for analysis: (i) primary or no education and (ii) secondary or higher education. Per capita income was obtained by dividing the total household income by the household size.

Fat and protein are important macronutrients for the growth of children. The main sources of fat and protein in the diet of the present study population were oil, dal/pulses, and meat/egg/fish among other foods. Information about per capita weekly consumption of oil, dal/pulses, and meat/egg/fish was derived from the household questionnaire where the adult respondent (in most cases the mother) was asked how often various items were consumed weekly in the household and the quantity of each item bought per week. Per capita weekly consumption of a specific item was derived by dividing the weekly purchase of that item by the number of family members. Specifically, weekly consumption of meat/egg/fish was derived by combining consumption of meat (in kg), eggs (1 egg ≈ 50 g), and fish (in kg).

2.4. Data Analysis. Basic characteristics of households and adolescents were described. Overall mean and standard deviation were obtained for height, weight, and BMI. We first compared the observed percentiles of height, weight, and BMI for the study population to the WHO and Indian reference populations. Percentages of stunting and thinness using the WHO and Indian reference populations were presented in bar charts. Not much is known about the correlation between height, weight, and BMI among adolescents of low-income and middle-income countries. We also computed Pearson correlation coefficients between these three measures separately for boys and girls. Descriptive statistics of independent variables are also presented.

The study subjects were recruited from 276 households and that resulted in more than one adolescent per household (171 households, 65%). The data on adolescents from the same household might be correlated and, hence, regression models used for the analysis included a household-specific random effect. The analysis was carried out using a generalized linear mixed model [24]. Age-adjusted means were obtained using linear regression of each (denoted by y) height, weight, and BMI over age (denoted by x) using

$$y_{ih} = b_0 + b_1 x_i + \epsilon_{ih} + u_h, \quad i = 1, \ldots, n_h, \ h = 1, \ldots, H, \quad (1)$$

where b_0 and b_1 are the fixed effects, x is the age, ϵ is the random error due to the model, and u is the household-specific random effect. Both ϵ and u are assumed to be independent and normally distributed.

For the analysis of stunting and thinness, mixed effects logistic regression models were used. Regression analyses were carried out with age as an independent variable, and the other variables added to the model one by one. Multivariate analyses with age and consumption data were carried out in model 1, and in model 2, family information was added. The mixed effects logistic regression model specified in terms of the log odds is given as follows:

$$\log\left(\frac{p\left(y_{ih} = 1 \mid x_{ih}, b, h\right)}{p\left(y_{ih} = 0 \mid x_{ih}, b, h\right)}\right)$$
$$= b_0 + b_1 x_{1i} + b_2 x_{2i} + \cdots + b_p x_{pi} + u_h, \quad (2)$$
$$i = 1, \ldots, n_h, \quad h = 1, \ldots, H,$$

where y is a response variable (stunting or thinness), $x = (x_1, x_2, \ldots, x_p)$ is a vector of p independent variables, $b = (b_0, b_1, \ldots, b_p)$ is a vector of fixed effects, and u is the household-specific random effect.

All analyses were performed using the statistical computing environment R and the regression analyses were implemented using the glmer function from the package lme4 of R [25–27].

3. Results

3.1. Descriptive Statistics. The slum population was rather homogeneous with regard to native place (Maharashtra), mother tongue (Marathi), and eating habits. The major religion was Hindu (87%), followed by Muslim (10%), Buddhism (2%), and other (1%). Forty percent of the population belonged to scheduled caste (SC), 32% scheduled tribe (ST), 10% open, 9% other backward class (OBC), and 9% other caste. 51% houses were of type kaccha, 45% were of type pucca, and the rest 3% were semipucca.

The median ages (14 years) of boys and girls were the same (Table 1). 79% of boys and 82% of girls were currently studying and 52% (45%) of boys and 56% (41%) of girls described their general health as very good (good). 42% of the adolescents were in class 5–7 and 38% were in class 8–10, and 30% boys and 24% girls were engaged in earning money. 25% boys were smokers and 24% and 35% either chewed tobacco or used gutka. Among girls these percentages were the same (7%) but smaller compared to that of boys. 64% of mothers were at home while 18% worked as household helpers. The maximum percentage (44%) of fathers was labourers, 22% had small businesses, and 10% were in the service sector. Comparison of mean values showed that boys were taller than girls but there was no difference in the mean weight (Table 1). The 75th and 90th percentiles of height were higher by 7–9 cm among

Table 1: Means, standard deviation (SD), and percentiles of height, weight, and BMI for adolescents (combining 10–18 years) by sex.

	Boys ($N = 257$)						Girls ($N = 261$)					
	Mean (SD)	Percentiles					Mean (SD)	Percentiles				
		10	25	50	75	90		10	25	50	75	90
Age (years)	14 (2.5)	10	12	14	16	17	14 (2.3)	11	12	14	15	17
Height (cm)	150 (14)	131	139	149	162	169	147 (10)	131	140	148	155	158
Weight (kg)	37 (11)	23	29	36	45	50	37 (9)	25	30	38	43	48
BMI (kg/m^2)	16 (2)	13	15	16	18	19	17 (3)	14	15	17	19	21

Table 2: Means of height, weight, and BMI for adolescents by age and sex.

| Age (years) | Boys | | | | Girls | | | |
	N	Height (cm)	Weight (kg)	BMI (kg/m^2)	N	Height (cm)	Weight (kg)	BMI (kg/m^2)
10	27	134	25	14	16	136	28	14
11	30	138	29	15	36	139	30	15
12	40	142	32	15	40	142	33	15
13	31	146	35	16	31	144	35	16
14	25	151	38	16	33	147	38	16
15	21	155	41	17	40	150	40	17
16	32	159	44	17	26	153	43	17
17	29	163	47	18	22	156	45	18
18	22	167	50	18	17	158	48	18

boys compared to girls. The 10th, 25th, and 50th percentiles of weight were higher by about 2 kg among girls but the 75th and 90th percentiles were lower among girls compared to boys. The average BMI as well as percentiles were higher among girls than boys by 1-2 kg/m^2 (Table 1).

An age-wise summary of height and weight showed that height and weight increased with the increase in age in both sexes (Table 2). An average yearly increment in the mean height of boys was 3.6 cm, while that of girls was 2.4 cm, and an average yearly increment in the mean weight of boys was 2.7 kg, while that of girls was 2.2 kg. Girls were at least as tall as boys to the age of 12 years and the mean weight of girls showed a similar pattern to the age of 14 years. Boys tended to be taller than girls from the age of 13 years and heavier from the age of 15 years. The mean BMI for boys and girls was the same at all ages but showed increasing trend with age.

For boys, the Pearson's correlation coefficient between height and weight was 0.89, height and BMI was 0.50, and weight and BMI was 0.83, while for girls the same between height and weight was 0.76, height and BMI was 0.35, and weight and BMI was 0.87. For all adolescents combined, the Pearson's correlation coefficient between height and weight and between weight and BMI was 0.83, while it was lower between height and BMI (0.38), as observed in other studies.

3.2. Stunting and Thinness. The study population had lower median values (about 10 cm for height and 3 kg/m^2 for BMI) for all ages compared to both reference populations (Figure 1). The difference in median height narrowed after the age of 15 years but that of BMI remained the same. This was seen among boys as well as girls. It should be noted that the Indian reference population (of affluent urban adolescents)

had similar median values of BMI but slightly lower median heights compared to the WHO reference population. In the sequel, WHO and IND refer to the classifications based on the WHO and Indian reference populations, respectively. The percentages of stunting among boys (range WHO 13%–59% and IND 13%–41%) were similar using both the reference populations to the age of 12 years and after that the proportion was higher when the WHO reference population was used (except for the age 17 years, Figure 2). Among girls (range WHO 14%–44% and IND 4%–31%) the two classifications differed at all ages. Stunting showed an increasing trend with age among boys and a decreasing trend among girls. It was interesting to note that the proportion of stunted boys was lower compared to girls at ages 10 and 11 years, after which the trend was reversed.

The differences in the two classifications for thinness were much larger compared to stunting (Figure 3). The proportion of thinness, both among boys (range WHO 23%–52% and IND 0%–18%) and girls (range WHO 15%–38% and IND 4%–19%), first increased with age and then tapered off. Small proportions of overweight adolescent boys (range WHO 0%–8% and IND 0%–8%) were observed at ages 11, 15, and 16 years under the WHO but at the age of 14 years under both the classifications. Among girls (range WHO 0%–13% and IND 0%–10%) overweight was observed at ages 11, 12, 13, and 16 years under both classifications. For further analysis, stunting and thinness as defined by the Indian reference population were used.

3.3. Summary of Independent Variables (Table 3). The mean per capita income per month was INR 960 and INR 843 for boys and girls, respectively, which puts 60% boys and 68%

(a) Age versus median height for boys

(b) Age versus median height for girls

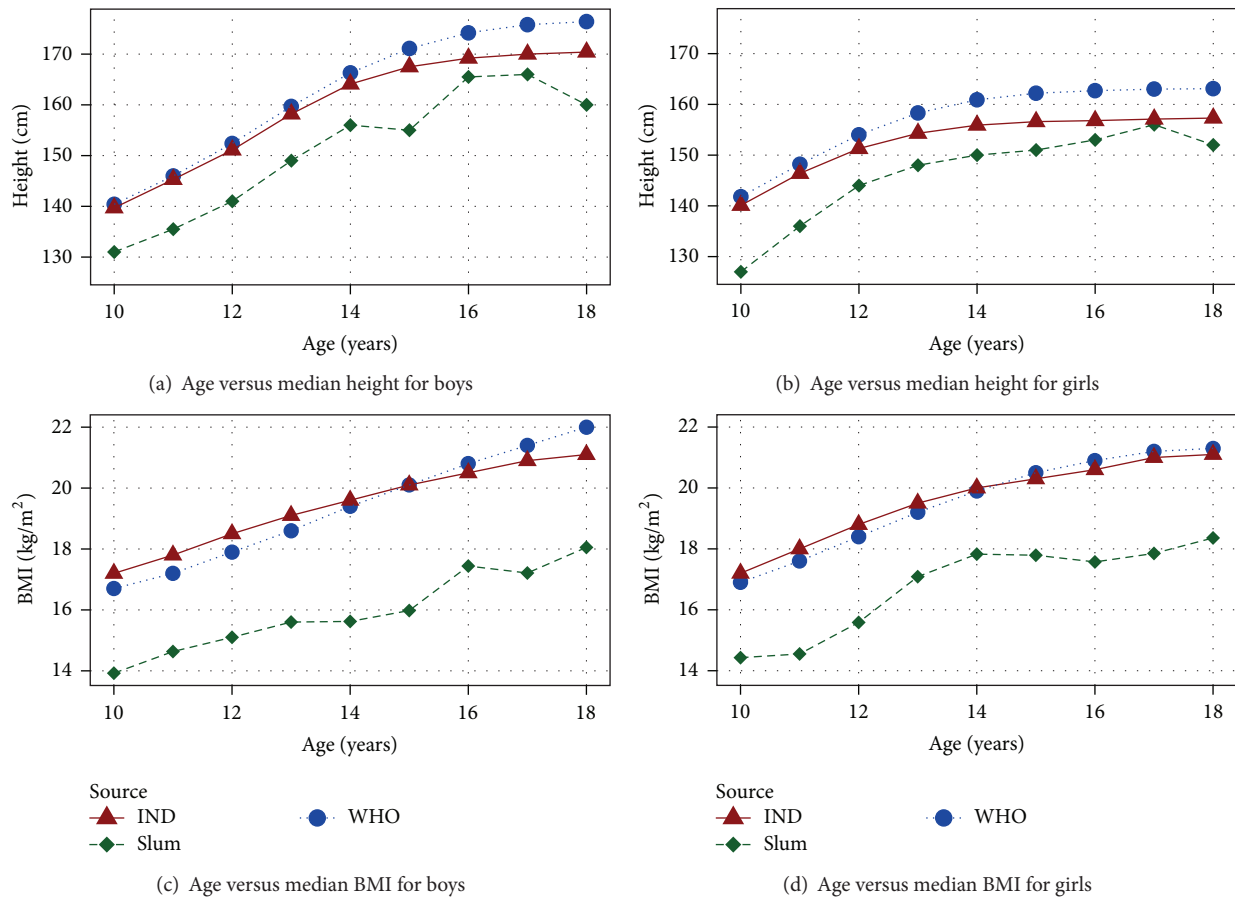(c) Age versus median BMI for boys

(d) Age versus median BMI for girls

FIGURE 1: Age versus median values of height and BMI of the study subjects (Slum), WHO, and Indian (IND) reference populations by sex.

TABLE 3: Mean, standard deviation (SD), and range (minimum, maximum) for dietary consumption data, income, household size, and percentage of mother's education by sex.

	Income* (INR)		Consumption of		Household size (%)			Mother's education (%)
		Oil* (kg)	Egg/meat/fish* (kg)	Dal/pulses* (kg)				
	Mean (SD)	Mean (SD) range	Mean (SD) range	Mean (SD) range	4 or less	5	More than 5	Primary or no
Boys (N = 257)	221 (140) (28, 1073)	0.23 (0.11) (0.02, 0.75)	0.13 (0.10) (0.00, 0.45)	0.08 (0.04) (0.00, 0.25)	35	30	35	49
Girls (N = 261)	194 (101) (29, 1035)	0.21 (0.10) (0.00, 0.75)	0.12 (0.09) (0.00, 0.45)	0.08 (0.05) (0.00, 0.40)	23	27	50	49

*Per capita weekly.

girls below the poverty line (below INR 961.1 per person per month for urban Maharashtra, [28]). 49% of mothers of the adolescents had primary or no education. The per capita weekly overall consumption of animal protein (meat, fish, and eggs, 120–130 g with SD of 100 g) as well as vegetable protein (dal/pulses, 80 g with SD of 40 g) was very low and similar in households with boys and girls. Intake of a source of energy, which was mainly oil (peanut oil in the study area), varied between negligible and 750 g per person per week. The distribution of household size differed between boys and girls with 50% girls having a household size of

more than 5 members while only 35% boys had more than 5 members. Except for consumption data on meat, egg, or fish (4% missing data), the proportion of missing data was less than 1% (Table 3).

3.4. Regression Analysis. A univariate regression analysis where log odds of stunting versus no stunting were modelled with age as an independent variable showed a significant effect in both boys and girls, but positive in boys and negative in girls (Table 4). An increase in age by one year increased the

TABLE 4: Stunting-regression coefficients (β) and 90% confidence intervals under the mixed effects logistic regression model for stunting by sex. Log odds of stunting versus no stunting were modeled. Each model included age and an additional covariate.

		Boys		Girls	
		β (CI)	exp(β) (CI)	β (CI)	exp(β) (CI)
Age		0.12* (0.01, 0.24)	1.13 (1.01, 1.27)	−0.18* (−0.35, −0.02)	0.83 (0.70, 0.98)
Household size	4 or less	Reference		Reference	
	5	0.28 (−0.41, 0.99)	1.33 (0.66, 2.69)	−0.88 (−1.87, 0.11)	0.41 (0.15, 1.12)
	More than 5	0.42 (−0.26, 1.11)	1.53 (0.77, 3.03)	−0.76 (−1.56, 0.03)	0.47 (0.21, 1.03)
Mother's education	Primary or no	Reference		Reference	
	Secondary or higher	−0.89* (−1.46, −0.33)[1]	0.41 (0.23, 0.72)	−1.42* (−2.32, −0.52)[3]	0.24 (0.10, 0.59)
Income	Standardized	0.11 (−0.15, 0.38)	1.12 (0.86, 1.46)	−1.02** (−1.64, −0.41)	0.36 (0.19, 0.66)
Consumption of	Oil	−0.89 (−3.62, 1.85)	0.41 (0.03, 6.36)	1.41 (−1.88, 4.69)	4.08 (0.15, 108.85)
	Dal/pulses	−0.90 (−7.68, 5.88)	0.41 (0.0005, 357.81)	3.84 (−2.78, 10.46)	46.53 (0.06, 34891.55)
	Egg/meat/fish	−2.93 (−6.23, 0.36)[2]	0.05 (0.002, 1.43)	0.49 (−3.53, 4.52)[4]	1.64 (0.03, 91.84)

[1] Age effect did not remain significant.
[2] Age effect became stronger, regression coefficient and CI were 0.14 (0.03, 0.27), P value = 0.05.
[3] Age effect became stronger, regression coefficient and CI were −0.22 (−0.40, −0.05), P value = 0.04.
[4] Age effect did not remain significant.
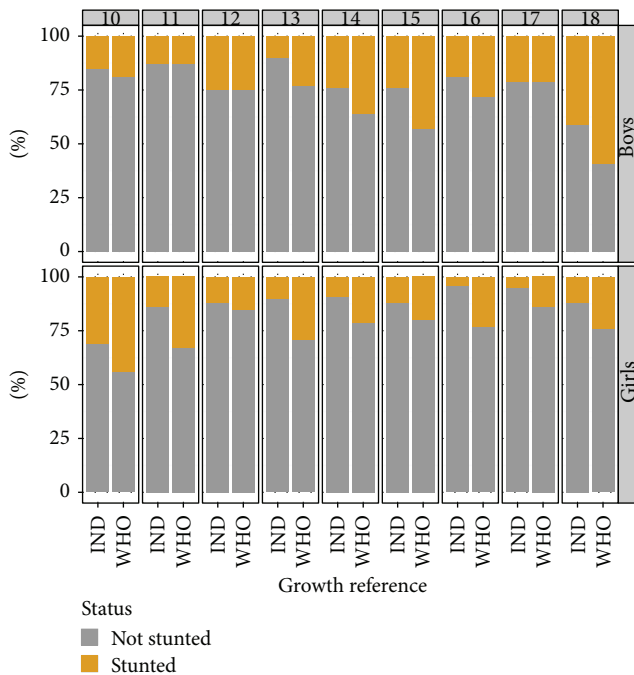*$0.01 \leq P$-value ≤ 0.10, and **P-value < 0.01.

FIGURE 2: Percentages of stunted and not stunted study subjects by age and sex using WHO and Indian (IND) reference populations.

FIGURE 3: Percentages of thin, normal, and overweight study subjects by age and sex using WHO and Indian (IND) reference populations.

odds of stunting among boys by 13%, whereas it reduced the odds by 17% among girls.

Further, bivariate regression analyses were carried out by adding the independent variables, namely, household size, mother's education, income, and dietary data on consumption of oil, egg/meat/fish and dal/pulses, one by one to the model in addition to age. Mother's education was significantly associated with stunting (Table 4). When moving from primary or no education to secondary or higher education of
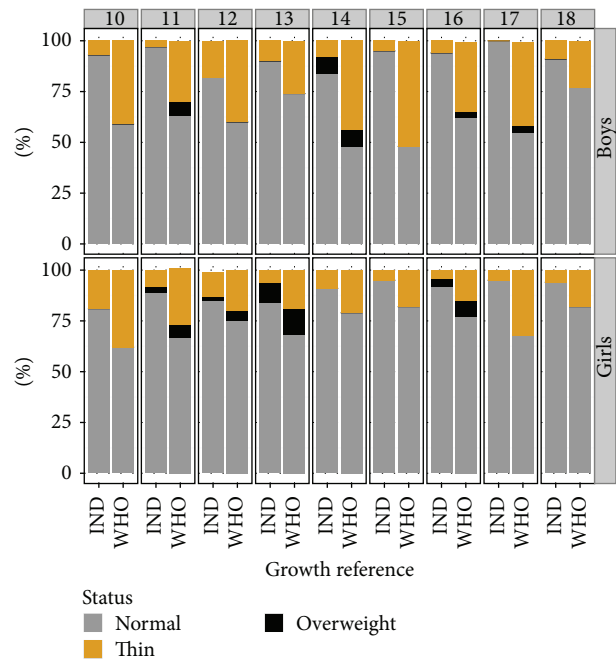
the mother, the odds of stunting reduced by 59% among boys and 76% among girls. Income was significantly associated with stunting among girls, with a ten standard deviation unit increase in income reducing the odds of stunting by 20% among girls. There was no significant effect of dietary data observed in this study.

The multivariate analysis under model 1 which included age and dietary data did not alter the age effect. The second model which in addition included mother's education,

Table 5: Thinness-regression coefficients (β) and 90% confidence intervals under the mixed effects logistic regression model for thinness by sex. Log odds of thinness versus normal BMI were modeled. Each model included age and an additional covariate.

		Boys		Girls	
		β (CI)	$\exp(\beta)$ (CI)	β (CI)	$\exp(\beta)$ (CI)
Age		−0.10 (−0.26, 0.06)	0.91 (0.77, 1.06)	−0.18* (−0.35, −0.02)	0.83 (0.70, 0.98)
	4 or less	Reference		Reference	
Household size	5	0.17 (−0.89, 1.23)	1.18	−0.88 (−1.87, 0.11)	0.41 (0.15, 3.42)
	More than 5	0.36 (−0.68, 1.41)	1.44 (0.51, 4.10)	−0.76 (−1.56, 0.03)	0.47 (0.21, 1.03)
Mother's education	Primary or no	Reference		Reference	
	Secondary or higher	0.12 (−0.71, 0.96)	1.13 (0.49, 2.61)	−1.42** (−2.32, −0.52)	0.24 (0.10, 0.59)
Income	Standardised	0.04 (−0.34, 0.43)	1.04 (0.71, 1.54)	−1.02** (−1.64, −0.41)	0.34 (0.19, 0.66)
	Oil	1.13 (−2.62, 4.87)	3.08 (0.07, 130.32)	1.40 (−1.88, 4.69)	4.08 (0.15, 108.85)
Consumption of	Dal/pulses	−7.44 (−19.26, 4.38)	0.0006 (0.43×10^{-8}, 79.83)	3.84 (−2.78, 10.46)	46.36 (0.06, 34891.55)
	Meat/egg/fish	−2.06 (−6.47, 2.35)	0.13 (0.002, 10.49)	0.49 (−3.53, 4.52)[1]	1.64 (0.03, 91.84)

[1] Age effect was not significant.

* $0.01 \leq P$-value ≤ 0.10, and ** P-value < 0.01.

household size and income did not change the results of univariate analysis of each of these variables (adjusted for age). For boys, age did not remain significant in the second model but mother's education remained significant and had a similar effect as described earlier. For girls, age, mother's education, and income remained significant and in addition household size was also significantly associated with stunting. When moving from a household size of 4 or less to more than 5, the odds of stunting among girls were reduced by 70% (*data not shown*).

Similarly, odds of thinness versus normal BMI were analysed under the regression models with age as an independent variable and then each of the other variables was added to the model. None of the independent variables showed significant association with thinness among boys (Table 5). However, for girls, age, mother's education, and income were significantly associated with thinness. When mother's education increased from primary or no education to secondary or higher education, the odds of thinness versus normal BMI were reduced by 76%. One unit increase in a girl's age reduced the odds by 17% while a ten-standard-deviation-unit increase in income reduced the odds by 66%. Once again, dietary data did not show any significant effect. Multivariate analysis including all the independent variables did not change the results of univariate analysis, and age, mother's education, and income remained significant for girls with similar effects as described above (*data not shown*).

4. Discussion

This study examined the nutritional status and possible associated factors, of adolescents from an economically deprived slum population which constitutes a sizeable proportion of the overall Indian urban population. With increasing urbanization, this population is likely to grow. The adolescents of the present study had lower mean height and weight but comparable BMI-for-age compared to those reported in other studies on school children from Indian cities [13, 16, 29, 30]

but higher height and weight but lower BMI compared to school children (10–17 years) from the rural area of Wardha, Maharashtra, and rural area of northern Karnataka [30, 31].

Adolescent growth spurt is a universal phenomenon and occurs in all children during adolescence, though it varies in intensity and duration from one child to another. Growth spurt among girls was observed around the age of 13 years and it was around this age when menarche was attained (median age at menarche of the study girls was 13.7 years, data not shown) after that the BMI tapered off and so did height. For boys it happened about 2 years later that was around 15 years of age. During the growth spurt, boys gained about 20 cm (range 10–30 cm) in height accompanied by a gain in weight of about 20 kg (range 7–30 kg). The peak velocity of height growth averaged about 10 cm per year. In girls the spurt was somewhat narrower in magnitude, and the peak height velocity was averaging about 8 cm per year. Similar observations were also made in other studies [29, 32]. The difference in size between adult men and women is to a large extent the result of the differences in adolescent growth spurt occurrence. In boys the spurt occurs later, allowing an extra period for growth, even at the slow prepubertal velocity and partly because of the greater intensity of the spurt itself; prior to it, boys and girls are practically of the same height [29].

The growth reference curves for India were derived using apparently healthy affluent Indian children [11] and the present slum population seemed to have lower anthropometric profile in comparison. The prevalence of stunting was higher than the prevalence of thinness among boys and girls. The phenomenon of the higher proportion of stunting may indicate that consumption of foods rich in protein responsible for height was far below the required level. We make an observation that the Indian reference population had a higher median BMI-for-age than the WHO reference population which was derived from several countries including India (Figure 1). The prevalence of stunting and thinness was reduced when using the Indian reference population compared to the WHO reference population and similar observations were also made in other studies [33].

The prevalence of stunting was higher among boys than girls after the age of 11 years and also the prevalence of thinness was higher among boys at all ages, though not showing such trend systematically (Figures 2 and 3). This could be because girls were nutritionally better off than boys [34]. The total proportion of stunting was higher among boys (21%) compared to girls (11%) in this study. This highlights a less researched question about boys suffering growth related issues and possibly nutritional deficiency as the focus of such research has been mostly on girls and women.

With regard to BMI-for-age, a high proportion (90%) of the study population had normal nutritional status. The overall prevalence of being overweight (1% boys and 2% girls) and thinness (8%) were low compared to other studies on urban children. In this paper, no association was observed between dietary data and nutritional status. One reason for this could be that the study population was rather homogeneous with regard to the food habits and to some extent, life style.

A study from rural Wardha observed a significantly higher prevalence of stunting among adolescents from the lower family income group [35]. Surprisingly, one study found that a larger number of over-5-year-old children in a household was associated with less child anthropometric failure than if there were fewer children [23].

The association between stunting and thinness with higher income and more family members among girls is in line with the rural Wardha study [35] and Gaiha's study [23]. The mother's education was found to be an important factor affecting stunting as well as thinness among boys and girls in accordance with other studies [35–37].

In summary, boys with a higher prevalence of stunting compared to girls might have suffered from high levels of chronic undernutrition, a consistent lack of consumption of required nutrients both in quantity and quality, and partly from untreated infections. Proper care is needed for growing boys to meet their nutritional requirement according to age. Mother's education was highly significant in reducing stunting among both sexes, and hence, educating the mothers of adolescents about their nutritional needs may help in improving adolescents' anthropometric profile and future health. A longitudinal study looking at anthropometry and dietary intake data would be needed for planning of a proper nutritional intervention for urban slum populations to overcome the problem of stunting.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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