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Physical Growth and Body Composition Assessment among Rural Adolescent Girls (10-16 Years) of Karbi Anglong, Assam, Northeast India

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ABSTRACT Physical growth and body composition assessment are of interest to the nutritionists and biological anthropologists due their variations and impact of nutrition, dietary habit, exercise, lifestyle, disease, sedentary behaviour, endocrine and genetic factors. The present community based cross-sectional investigation assesses the physical growth pattern and body composition characteristics and their associations with a set of anthropometric growth variables among rural adolescent girls of Assam, Northeast India. This cross-sectional investigation was undertaken among 542 adolescents (aged 10-16 years) of Karbi Anglong, Assam, India. A set of anthropometric measurements of weight, height, mid-upper arm circumference and skin-fold thickness were recorded by standard procedures. Standard anthropometric variables were used to assess the physical growth and body composition status. The age-specific mean values of BMI, PBF, FM, FFM, UMA, and UFA increased with ages ($p<0.05$). BMI and PBF were significantly correlated with FM, FFM, FMI, FFMI UMA and UFA ($p<0.05$). Linear regression analysis has shown the significant association between anthropometric and body composition variables with BMI and PBF ($p<0.05$). Comparison with growth references shown poor physical growth and body composition attainment among adolescent girls. The present investigation provides anthropometric data on physical growth and body composition variables in comparison to population. In-depth studies are also necessary for identifying the factors responsible for the physical growth retardation and body composition among adolescents.

INTRODUCTION

Physical growth and body composition assessment of an individual/population are of interest to the nutritionists and biological anthropologists due to their variation and impact of several intrinsic and extrinsic factors of nutrition, dietary habit, exercise, lifestyle, disease, sedentary behaviour, environment, endocrine and genetic factors. The rural environment is the important factor which delay the optimal physical growth pattern and body composition in many developing countries (Semproli and Gualdi-Russo 2007; Olivieri et al. 2008; Andrissi et al. 2013; Xu and Hang 2017; Zong et al. 2017). Adolescence is a decisive period of rapid physical growth attainment and development or maturity with multiple physiological changes occurring between the childhood and adulthood of human life cycle and the body composition transforming with differential changes taking place between sexes (WHO 1995; Wells 2007). Physical growth and body composition assessment can play an important role in nutritional status for the effect of age, sex, ethnic, geographic, environmental, socio-economic conditions, sedentary behavior, physical activity, disease and genotype or genetic factors and provides a useful sign of the health and nutritional status (Eveleth and Tanner 1990; Rolland-Cachera 1993; Rogol et al.2002; Hall et al. 2007; Rogol 2010; Wells 2010; Sen and Mondal 2013; Xue et al. 2016; Griffiths et al. 2016; Rengma et al. 2016; Sharma et al. 2017). The anthropometry is non-invasive, inexpensive and easy-to-use technique still widely used as an important method of choice to assess the physical growth and body composition in epidemiological/field and clinical investigations (Frisancho 1990; Rolland-Cachera 1993; Banerjee et al. 2009; Basu et al. 2010; Sen and Mondal 2013; Frignani et al. 2015; Tinggaard et al. 2016; Debnath et al. 2017; Sharma et al. 2017; Zong et al. 2017). Several investigations have used various anthropometric measurements to report physical growth patterns among children and adolescents (Adak et al.

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2000; Rao et al. 2000; Mitra et al. 2002; Chakrabarty and Bharati 2008; Olivieri et al. 2008; Banerjee et al. 2009; Chatterjee et al. 2009; Mondal and Sen 2010a; Amusa et al. 2011; Mondal and Terangpi 2014; Singh and Mondal 2014; Mamidi et al. 2016; Debnath et al. 2017; Mondal et al. 2017).

Body composition assessment estimates the amount, distribution and variations of body adiposity [Fat mass (FM)] and/or muscle mass [Fat free mass (FFM)] and used as an important component in the nutrition and health outcomes of children and adolescents (Nakao and Komiya 2003; Wells and Fewtrell 2006; Wells 2010; Thibault et al. 2012; Sen and Mondal 2013; Nightingale et al. 2013; Zhang and Wang 2013; Griffiths et al. 2016; Xue et al. 2016). Body mass index (BMI= weight/height, kg/m^2) is an anthropometric measure which determines body composition, predicts the amount of body adiposity and shape but is not able to desegregate the proportions of body adiposity to lean body mass in clinical/epidemiological investigations (Wells 2010; Thibault et al. 2012; Thibault and Pichard 2012; Chung 2015; Alpizar et al. 2017). The BMI can be better expressed in terms of the FM index (FMI) and FFM index (FFMI) and is discrete and can be adjusted for body size and composition (VanItallie et al. 1990; Demerath et al. 2006; Wells 2010; Griffiths et al. 2016; Alpizar et al. 2017). The desegregation of BMI in terms of FM and FFM needs the help of the anthropometric measurements and body composition (VanItallie et al. 1990; Schutz et al. 2002; Wells 2010; Nightingale et al. 2013; Sen and Mondal 2013; Xue et al. 2016). The MUAC and triceps skinfold (TSF) thickness was used to calculate the upper arm composition in terms of upper-arm muscle area (UMA) and upper-arm fat area (UFA) (Frisancho 1990; Derman et al. 2002; Chomtho et al. 2006; Hall et al. 2007; Chowdhury and Ghosh 2009; Sen et al. 2011; Singh and Mondal 2014; Debnath et al. 2017). Several research field, epidemiological and clinical investigations have reported the significant association of diseases, biochemical changes, clinical diagnosis and undernutrition with UMA and UFA (Sen et al. 2011; Piratelli and Telarolli 2012; Hoffmeister et al. 2013; Salvioni et al. 2015; EmamiArdestani et al. 2016; Debnath et al. 2017). Studies have also reported that sexual dimorphism in age-specific body composition and adiposity trend among children and adolescents (He et al. 2004; Semproli and Gualdi-Russo 2007; Chowdhury and Ghosh 2009; Basu et al. 2010; Taylor et al. 2010; Amusa et al. 2011; Sen et al. 2011; Sen and Mondal 2013; Frignani et al. 2015; Tinggaard et al. 2016; Debnath et al. 2017; Qi et al. 2017).

The attainments of inadequate physical growth and body composition are attributed to their rural living condition, food consumption, environment, disease prevalence and availability of healthcare facilities in population. Several studies have reported the inadequate nutritional status and body composition among children and adolescents in India (Rao et al. 2000; Venkaiah et al. 2002; Medhi et al. 2007; Banerjee et al. 2009; Basu et al. 2010; Mondal and Sen 2010a,b; Sen and Mondal 2013; Singh and Mondal 2014; Rengma et al. 2016; Debnath et al. 2017). India comprises of numerous indigenous populations and has an enormous amount of ethnic diversity (Indian Genome Variation Consortium 2008). The country has the largest number of endogamous indigenous people in the world and includes diverse tribal, non-tribal and caste populations. The literature search reveals that the prevalence of undernutrition is a major nutritional problem among the ethnic populations of the Northeast India (Khongsdier 2005; Maken and Varte 2012; Basu et al. 2013; Mondal and Terangpi 2014; Singh and Mondal 2014; Duwarah et al. 2015; Mondal et al. 2015; Rengma et al. 2016; Bharali et al. 2017; Sharma et al. 2017). The rural populations are more vulnerable and underprivileged in terms of poverty, literacy, nutritional status and poor healthcare situations in India. Literature search reveals that sporadic studies are reported on body composition assessment among adolescent girls in Northeast, India (Basu et al. 2010; Rajkumari et al. 2012; Singh and Mondal 2014). Moreover, the relationship between the undernutrition, disease morbidity and physical performances needs a precise evaluation of body composition.

Objectives

The aims of the present investigation are to find out the physical growth pattern and body composition, and age-specific effect on different anthropometric, physical growth and body composition variables among the rural adolescent girls of Assam India. Further, the present investigation also compares the physical growth variables with international growth references.

METHODOLOGY

Subjects and Study Area

The present cross-sectional investigation was carried out among 542 adolescent girls aged 10-16 years in rural areas of Diphu, Karbi Anglong, Assam. The district Karbi Anglong (25º 33' and 26º35' N latitude and 92º10' to 93º50' E longitude) is one of the 33 administrative districts of Assam and stretches an area of 10,434 km^2 of Assam, India. National census of 2011, data reveals 965,280 individuals (493,482 male; 471,798 female; Sex ratio 951) with an average literacy rate of 59.52 percent (male: 56.82% female: 43.18%) in the district Karbi Anglong. The standard sample size estimation procedure was used to estimate the minimum number of sample size required for a reliable estimate to any health or anthropometric investigation (Lwanga and Lemeshow 1991). The expected population proportion of fifty percent, absolute precision of five percent and confidence interval of ninety-five percent were taken into consideration in this method. The minimum sample size in the present study was estimated to be about 385 subjects. A total sample of 580 girls was approached, out of which 542 girls in the age group of 10-16 years were selected using simple random sampling in the present investigation. Hence, the total sample size of the present investigation was found higher than the estimated sample size. The participation rate of the subjects in the investigation was 93.45 percent. Special care was taken so that each age had a minimum of 50 girls. Adolescent girl's age group found not in the age group of 10-16 years or without appropriate birth records were excluded. The subjects free from any disease or physical disability or any previous surgery episodes were excluded. Data of the present investigation were collected from 3 secondary schools in the above-mentioned region. These schools have a substantial number of students belonging to heterogeneous populations including tribal population of Karbi, Bodo, Dimasa, Rengma Naga and several heterogenous Bengali, Nepali and Assamese speaking caste groups. The total student strength of these covered schools was almost identical. These schools were selected for they were nearest and had easy accessibility by road from the Diphu town. The age of the subjects was recorded from the school records and also verified from their birth certificates and/or official documents issued by Government office. The permission of the investigation was received from school authorities prior to conducting the field work. Parents of the subjects were informed and a verbal consent was taken prior to recording the anthropometric and socio-economic and demographic variables. The present investigation was carried out in accordance with the ethical guidelines of human experiments as mentioned in the Helsinki Declaration (Portaluppi et al. 2010).

Collection of Anthropometric Data

Anthropometric measurements were recorded using the standard procedures of Hall et al. (2007). Height was recorded with the help of anthropometer rod to the nearest 0.1 cm. The subjects were made to stand on a horizontal platform with both heels together without footwear. The head was kept stretched upward to the fullest extent in the Frankfurt horizontal plane. The horizontal arm of the anthropometer was brought down to touch the vertex. Body weight of the subject was recorded using a portable weighing scale to the nearest 0.5 kg. The individuals were barefoot and wearing minimum clothing at the time of measurement. MUAC was measured on the left arm of each individual with the arm hanging relaxed. The skin-fold measurements of TSF and sub-scapular (SSF) were measured on the left side of the body to the nearest to 0.2 mm using a Harpenden skin-fold caliper calibrated to exert a constant pressure of 10 gm/mm^2. The skin-folds are picked up between the thumb and the forefinger about one centimeter above the mid-point, taking care not to include the underlying muscle. The tips of the skin-fold caliper are applied at an equal depth equal to the skin-fold. The technical error measurement (TEM) was calculated following the method of Ulijaszek and Kerr (1999) to determine the accuracy of the measurements. A total of 50 children, other than those covered in the present investigation were measured by two of the researchers (JS and NM).

$TEM=\sqrt{(\Sigma D^2/2N)}$ [D= Difference between the measurements, N=Number of individuals measured]. The co-efficient of reliability (R) of the anthropometric measurements were calculated from TEM using the following equation:

$R=\{1-(TEM)^2/SD^2$, where, SD=Standard deviation of the measurements.

Very high TEM values were recorded for the both intra-and inter observer TEM analysis. The intra and inter-observer TEM were found within the cut-off values of 0.95 as suggested by Ulijaszek and Kerr (1999), hence the measurements recorded in the present investigation were reliable and reproducible. All the measurements in the course of the present investigation were subsequently recorded by one of the researchers (JS).

Assessment of Body Composition

The assessment of body composition among the adolescent girls was done using following standard equations of BMI:

BMI= weight/height, (kg/m^2) (WHO 1995).

The following equations of Slaughter et al. (1988) were used to estimate the percent of body fat (PBF): $PBF= 1.33 (TSF + SSF)^2 - (0.013 (TSF + SSF)^2 - 2.5$

The following standard equations were used to assess the proportion of Fat mass (FM), Fat-free mass (FFM), Fat mass index (FMI) and Fat-free mass index (FFMI) (VanItallie et al. 1990; Wells 2000):

$FM (kg) = (PBF/100) \times Weight (kg)$

$FFM (kg) = Weight (kg) - FM (kg)$

$FMI (kg/m^2) = FM/ Height^2 (m^2)$

$FFMI (kg/m^2) = FFM/ Height^2 (m^2)$

The upper arm composition was calculated using the MUAC and TSF according to the standard equations of Frisancho (1990):

$UMA (cm^2) = [MUAC(cm) - \{TSF(cm)\times ð\}^2/4ð]$

$UFA (cm^2) = \{(MUAC)^2(cm)/(4\times ð)\} - UMA$

Statistical Analysis

The statistical data analysis was done using the statistical package of social sciences (SPSS version 19.0). The One-Sample Kolmogorov-Smirnov test was used to compare the observed cumulative distribution functions for each anthropometric variable with respect to a specified theoretical distribution. In most cases, it was subsequently found that the values were statistically not significant for the anthropometric variables ($p>0.05$).The descriptive statistics (mean± standard deviation) was used to describe anthropometric variables. One way analysis of variance (ANOVA) was done to assess the age-specific mean difference in anthropometric and body composition variables. Pearson correlation coefficient analysis was done to find out the relationship between anthropometric and body composition variables. The linear regression analysis was done to assess the association of anthropometric and body composition variables of BMI and PBF. A p-value of <0.05 and <0.01 was considered to be statistically significant.

RESULTS

Age-specific descriptive statistics (mean ±SD) and subject distribution of anthropometric and body composition variables among adolescent girls are presented in Table 1. The age-specific mean weight and height increased with age among girls, except in 16 years. The age-specific mean MUAC, TSF and SSF increased with age. The age-specific mean BMI, FM, FFM, FMI, FFMI, UMA increased with age, except in 16 years (in FM and FMI). The age-specific highest positive attainment of growth spurt was recorded in height (4.47 cm), MUAC (1.71 cm), TSF (1.81 mm), SSF (1.70 mm), PBF (1.63%), FM (1.50 kg/m^2), UMA (2.68 cm^2) and UFA (2.70 cm^2) in girls of 11 years, but the greater growth attainments are observed in BMI (0.75 kg/m^2), FFM (2.07 kg/m^2) in 12 years among adolescents. The age-specific mean BMI ranged from 16.50 kg/m^2 (in 10 years) to 19.79 kg/m^2 (in 16 years). The age-specific mean PBF was found higher and lower among 13 years (27.10%) and 10 years (13.49%). The age-specific mean UFA was found higher among 13 years (15.69 cm^2) and lower among 11 years (11.09 cm^2) adolescent girls. Using ANOVA, the age-specific mean differences among the age groups were significant in weight (F= 44.65), height (F= 47.29), MUAC (F= 26.52), TSF (F= 4.33), SSF (F= 9.24), BMI (F= 20.74), PBF (F= 8.99), FM (F= 26.77), FFM (F= 50.01), FMI (F=14.90), FFMI (F= 20.28), UMA (F= 24.61) and UFA (F= 10.84) using ANOVA ($p<0.01$) (Table 1).

Correlation Coefficient Analysis Between Anthropometric and Body Composition Variables

The results of the Pearson correlation analysis between anthropometric and body composition variables among adolescent girls are presented in Table 2. The correlation co-efficient analysis showed a positive significant association of BMI with PBF (r= 0.541), FM (r= 0.848), FFM (r= 0.847), FMI (r= 0.878), FFMI (r= 0.936), UMA (r= 0.671) and UFA (r= 0.661). The correlation co-efficient analysis also showed a positively significant ($p<0.01$) correlation of PBF with

Table 1: Age-specific subject distribution and descriptive statistics (mean ±SD) of anthropometric and body composition variables among adolescent girls

Age	*Subjects (N=542)*	*Weight (kg)*	*Height (cm)*	*MUAC (cm)*	*TSF (mm)*	*SSF (mm)*	*BMI (kg/m²)*	*PBF (%)*	*FM (kg)*	*FFM (kg)*	*FMI (kg/m²)*	*FFMI (kg/m²)*	*UMA (cm²)*	*UFA (cm²)*
10 years	68	32.01 ±5.75	138.82 ±7.45	18.09 ±2.12	13.89 ±3.55	13.31 ±3.76	16.50 ±1.82	23.49 ±4.06	7.65 ±2.36	24.36 ±3.78	3.91 ±0.98	12.58 ±1.17	15.29 ±4.53	11.09 ±3.25
11 years	62	35.47 ±8.47	143.29 ±8.34	19.80 ±2.72	15.70 ±4.22	15.01 ±5.04	17.07 ±2.66	25.12 ±4.51	9.15 ±3.47	26.32 ±5.33	4.36 ±1.34	12.71 ±1.53	17.97 ±5.69	13.79 ±4.77
12 years	57	38.61 ±6.97	146.85 ±6.56	20.40 ±2.47	16.10 ±4.02	16.36 ±5.21	17.82 ±2.39	26.08 ±3.69	10.21 ±2.94	28.39 ±4.41	4.70 ±1.15	13.12 ±1.45	19.12 ±5.50	14.46 ±4.43
13 years	95	41.67 ±7.85	148.82 ±6.08	21.12 ±2.53	16.91 ±3.94	17.83 ±5.45	18.72 ±2.74	27.10 ±3.31	11.42 ±3.10	30.25 ±5.15	5.12 ±1.20	13.60 ±1.74	20.26 ±5.97	15.69 ±4.49
14 years	103	42.64 ±5.70	150.80 ±6.17	21.55 ±2.12	16.23 ±4.23	17.35 ±4.85	18.71 ±1.95	26.61 ±3.26	11.44 ±2.51	31.20 ±3.67	5.01 ±0.95	13.71 ±1.31	21.74 ±4.19	15.56 ±4.83
15 years	80	46.81 ±7.04	153.65 ±6.12	22.32 ±2.57	16.53 ±4.25	18.34 ±5.22	19.78 ±2.45	27.03 ±3.76	12.77 ±3.13	34.03 ±4.54	5.39 ±1.20	14.39 ±1.56	23.67 ±5.58	16.51 ±5.29
16 years	77	46.23 ±6.61	152.72 ±5.65	22.18 ±2.72	15.68 ±3.89	15.96 ±4.89	19.79 ±2.40	25.69 ±3.32	11.99 ±2.87	34.23 ±4.26	5.12 ±1.10	14.66 ±1.57	24.07 ±6.22	15.64 ±5.18
F-value		44.65*	47.29*	26.51*	4.33*	9.24*	20.74*	8.99*	26.77*	50.01*	14.90*	20.28*	24.61*	10.84*

*p<0.01

FM (r= 0.818), FFM (r= 0.348), FMI (r= 0.215), UMA (r= 0.248) and UFA (r= 0.847). The positive correlation co-efficient was recorded between FM with FFM (r= 0.806), FMI (r= 0.953), FFMI (r= 0.640), UMA (r= 0.572) and UFA (r= 0.845). The upper arm composition variables such as UMA and UFA have also shown a positively correlated coefficient value with the different anthropometric and body composition variables among adolescents (p<0.01).

Linear Regression Analysis of Age with Different Anthropometric and Body Composition Variables

Linear regression analysis was done to assess the dependency of age on the anthropometric and body composition variables among the adolescent girls as depicted in Table 3. The results of the regression analysis showed that age positively influences BMI (t= 10.88), UMA (t = 12.03), PBF (t = 4.58), FM (t= 11.55), FFM (t = 17.11), UFA (t = 6.78), FMI (t = 8.27), FFMI (t= 10.88), MUAC (t= 11.92), TSF (t= 2.75) and SSF (t = 4.83) among the adolescent girls. The age dependency was found significant with BMI, UMA, PBF, FM, FFM, UFA, FMI, FFMI, MUAC, TSF and SSF (p<0.01). The analysis of R^2-showed that FFM (R^2= 0.35), UMA (R^2= 0.21), MUAC (R^2= 0.21) and FM (R^2= 0.20) have greater associations with the age (p<0.01) (Table 3).

Linear Regression Analysis of BMI with Different Anthropometric and Body Composition Variables

Linear regression analysis was done to assess the dependency of BMI on the anthropometric and body composition variables among adolescents as depicted in Table 3. The results of the regression analysis showed that BMI positively influences UMA (t = 21.02), PBF (t = 24.93), FM (t = 37.20), FFM (t = 37.06), UFA (t = 20.48), FMI (t = 42.71), FFMI (t= 61.77), MUAC (t = 28.64), TSF (t = 11.88) and SSF (t = 16.38) among the adolescent girls. The BMI dependency was found significant with UMA, PBF, FM, FFM, UFA, FMI, FFMI, MUAC, TSF and SSF (p<0.01). The analysis of R^2 showed that FM (R^2 = 0.72), FFM (R^2 = 0.72), FMI (R^2 = 0.77) and FFMI (R^2 = 0.88) have greater associations with the BMI (p<0.01) (Table 4).

Table 2: Pearson correlation coefficient analysis of anthropometric and body composition variables among adolescent girls

Variables	*BMI*	*PBF*	*FM*	*FFM*	*FMI*	*FFMI*	*UMA*	*UFA*
BMI	1	0.541*	0.848*	0.847*	0.878*	0.936*	0.671*	0.661*
PBF	0.541*	1	0.818*	0.348*	0.871*	0.215*	0.248*	0.847*
FM	0.848*	0.818*	1	0.806*	0.953*	0.640*	0.572*	0.845*
FFM	0.847*	0.348*	0.806*	1	0.676*	0.843*	0.688*	0.500*
FMI	0.878*	0.871*	0.953*	0.676*	1	0.654*	0.525*	0.869*
FFMI	0.936*	0.215*	0.640*	0.843*	0.654*	1	0.675*	0.406*
UMA	0.671*	0.248*	0.572*	0.688*	0.525*	0.675*	1	0.407*
UFA	0.661*	0.847*	0.845*	0.500*	0.869*	0.406*	0.847*	1

*p<0.01

Table 3: Linear regression analysis of anthropometric and body composition variables with age as the dependent variable among adolescents girls

Variables	*Constant*	*B*	*Standard error*	*R^2*	*t*	*P*
BMI	7.41	0.31	0.03	0.18	10.88	0.00
UMA	10.19	0.15	0.01	0.21	12.03	0.00
PBF	10.66	0.10	0.21	0.04	4.58	0.00
FM	10.39	0.26	0.02	0.20	11.55	0.00
FFM	6.98	0.21	0.01	0.35	17.11	0.00
UFA	11.58	0.11	0.02	0.08	6.78	0.00
FMI	10.61	0.53	0.06	0.11	8.27	0.00
FFMI	6.44	0.50	0.05	0.18	10.88	0.00
MUAC	6.59	0.32	0.03	0.21	11.92	0.00
TSF	12.32	0.06	0.02	0.01	2.75	0.00
SSF	11.95	0.08	0.02	0.04	4.83	0.00

Table 4: Linear regression analysis of anthropometric and body composition variables with BMI as the dependent variable among adolescents girls

Variables	*Constant*	*B*	*Standard error*	*R^2*	*t*	*P*
UMA	12.53	0.29	0.01	0.45	21.02	0.00
PBF	8.87	0.37	0.03	0.29	14.93	0.00
FM	11.21	0.67	0.02	0.72	37.20	0.00
FFM	6.44	0.40	0.11	0.72	37.06	0.00
UFA	13.27	0.35	0.02	0.44	20.48	0.00
FMI	9.30	1.89	0.04	0.77	42.71	0.00
FFMI	-1.70	1.48	0.02	0.88	61.77	0.00
MUAC	3.27	0.73	0.03	0.60	28.64	0.00
TSF	13.86	0.29	0.02	0.21	11.88	0.00
SSF	13.69	0.29	0.02	0.33	16.38	0.00

Linear Regression Analysis of PBF with Different Anthropometric and Body Composition Variables

The results of the linear regression analysis were done to assess the dependency of PBF on the different anthropometric and body composition variables among adolescent girls is depicted in Table 4. The results of the regression analysis showed that PBF positively influences UFA (t = 37.07), UMA (t= 5.96), FM (t= 31.10), FFM (t= 8.62), FMI (t =41.11), FFMI (t= 5.01), MUAC (t= 17.91), TSF (t= 42.12) and SSF (t= 43.73) among the adolescent girls. The PBF dependency was found significant with UMA, FM, FFM, UFA, FMI, FFMI, MUAC, TSF and SSF (p<0.01). The analysis of R^2- showed that UFA (R^2= 0.72), FMI (R^2=0.76), TSF (R^2 = 0.76) and SSF (R^2 = 0.78) have greater associations with the PBF among adolescent girls (p<0.01) (Table 5).

Table 5: Linear regression analysis of anthropometric and body composition variables on PBF as the dependent variable among adolescents girls

Variables	*Constant*	*B*	*Standard error*	*R^2*	*t*	*P*
UFA	0.66	0.66	0.02	0.718	37.07	0.00
UMA	22.79	0.16	0.03	0.062	5.96	0.00
FM	15.75	0.95	0.03	0.670	33.10	0.00
FFM	18.78	0.24	0.03	0.121	8.62	0.00
FMI	12.70	2.74	0.07	0.758	41.11	0.00
FFMI	19.24	0.50	0.10	0.046	5.10	0.00
MUAC	8.51	0.84	0.05	0.373	17.91	0.00
TSF	13.10	0.81	0.02	0.758	41.12	0.00
SSF	15.28	0.65	0.02	0.780	43.73	0.00

DISCUSSION

The anthropometry technique has been widely used and most practical technique to assess the age/sex-specific variation in body size proportions, physical growth, body composition and nutritional status assessment of an individual/populations (Rolland-Cachera 1993; Rolland-Cachera et al. 1997; Derman et al. 2002; Chakrabarty and Bharati 2008; Banerjee et al. 2009; Basu et al. 2010; Taylor et al. 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014; Debnath et al. 2017; Sharma et al. 2017). There are several anthropometric indicators used to provide the indirect assessment of body composition such as BMI, PBF, FM, FFM, FMI, UMA and UFA. The body composition measures are effective in determining the nutritional status among children and adolescents belonging to the vulnerable segment of a population (Wells 2007, 2010; Olivieri et al. 2008; Chowdhury and Ghosh 2009; Sen et al. 2011; Basu et al. 2013; Sen and Mondal 2013; Singh and Mondal 2014; Debnath et al. 2017). Deficiency of the required nutrients may lead to the prevalence of chronic undernutrition and/or inadequate physical growth attainment and body composition status, which is identified with reduced lean body mass, low muscular strength and working capacity (WHO 1995). The poor attainment of physical growth and body composition leads to several physical manifestations including delays in menarche attainments and poor reproductive outcomes or low birth weight (WHO 1995). The results of the present investigation showed the significant difference in age-specific mean anthropometric and body composition variables among girls ($p<0.01$) (Table 1). The results showed that the age-specific greater growth spurts in anthropometric variables of height, weight, MUAC, TSF and SSF were recorded among adolescent girls as they approached puberty in 11-12 years girls (Table 1). Similar studies have reported the greater acceleration in physical growth and adiposity measurements among adolescents during puberty (Hauspie et al. 1980; Rao et al. 2000; Chatterjee et al. 2009; Mondal and Sen 2010b; Sen and Mondal 2013; Rengma et al. 2016). The body composition during adolescence changes with age (Rodríguez et al. 2004; Demerath et al. 2006; Wells 2007; Sen and Mondal 2013). The age-specific increase in body weight, height, MUAC, TSF, SSF, BMI, FM, FFM, FMI, FFMI, UMA and UFA could be due to the rapid physical growth occurring during the adolescent period (Table 1). Several studies have reported the age-specific significant increase in physical growth and body composition variables during adolescence (Demerath et al. 2006; Chakrabarty and Bharati 2008; Banerjee et al. 2009; Singh and Mondal 2014; Roy et al. 2016; Rengma et al. 2016; Sharma et al. 2017). The results of the linear regression analysis have shown the significant association of age with anthropometric and body composition variables ($p<0.01$) (Table 3). Several investigations have reported the age/sex and ethnic-specific variation in physical growth and body composition among children and adolescents (Reddy and Rao 2000; Medhi et al. 2007; Chakrabarty and Bharati 2008; Amusa et al. 2011; Nightingale et al. 2013; Sen and Mondal 2013; Roy et al. 2016; Debnath et al. 2017; Mondal et al. 2017).

The physical growth attainments, rapid growth velocity and pubertal development are the key markers of health and nutritional status status during childhood to adolescence (WHO 1995; Wells 2007). The variation in these indicators are attributed to age, sex, ethnic, pubertal development, nutritional status, dietary habit, sedentary lifestyle and psychosocial status. Physical growth attainment reflects living conditions, with major implications for health in the population (Eveleth and Tanner 1991). The attainment of poor growth and body composition may be attributed to the nutritional deprivation or improper access of food and poor socio-economic condition during the early stage of life or childhood. The age-specific comparison of mean height, weight and BMI values with different percentiles values (5^{th} to 95^{th}) values of US children (Frisancho 1990) and the CDC (Kuczmarski et al. 2002) show poor physical growth status and values were observed lower than the 50^{th} percentiles growth reference among adolescent girls (Fig.1). The inadequate/poor growth attainment in weight and height were also reported in other tribal and non-tribal adolescents in India (Reddy and Rao 2000; Mitra et al. 2002; Rao et al. 2006; Medhi et al. 2007; Singh and Mondal 2014; Mondal and Terangpi 2014; Roy et al. 2016; Mondal et al. 2017) while compared to the US children (Frisancho 1990), CDC (Kuczmarski et al. 2002) and Indian reference population (ICMR 1972). The mean height and weight of adolescent girls of the present investigation were compared with Indian adolescents (ICMR 1972), Sugalis tribal adolescents of Andhra Pradesh (Reddy and Rao 2000), Kamar tribal of Chhattisgarh (Mitra et al. 2002), Shabar tribe of Orissa (Chakrabarty and Bharati 2008), Bengali adolescents (Banerjee et al. 2009), Sonowal Kachari tribe of Assam (Singh and Mondal 2014), Indian

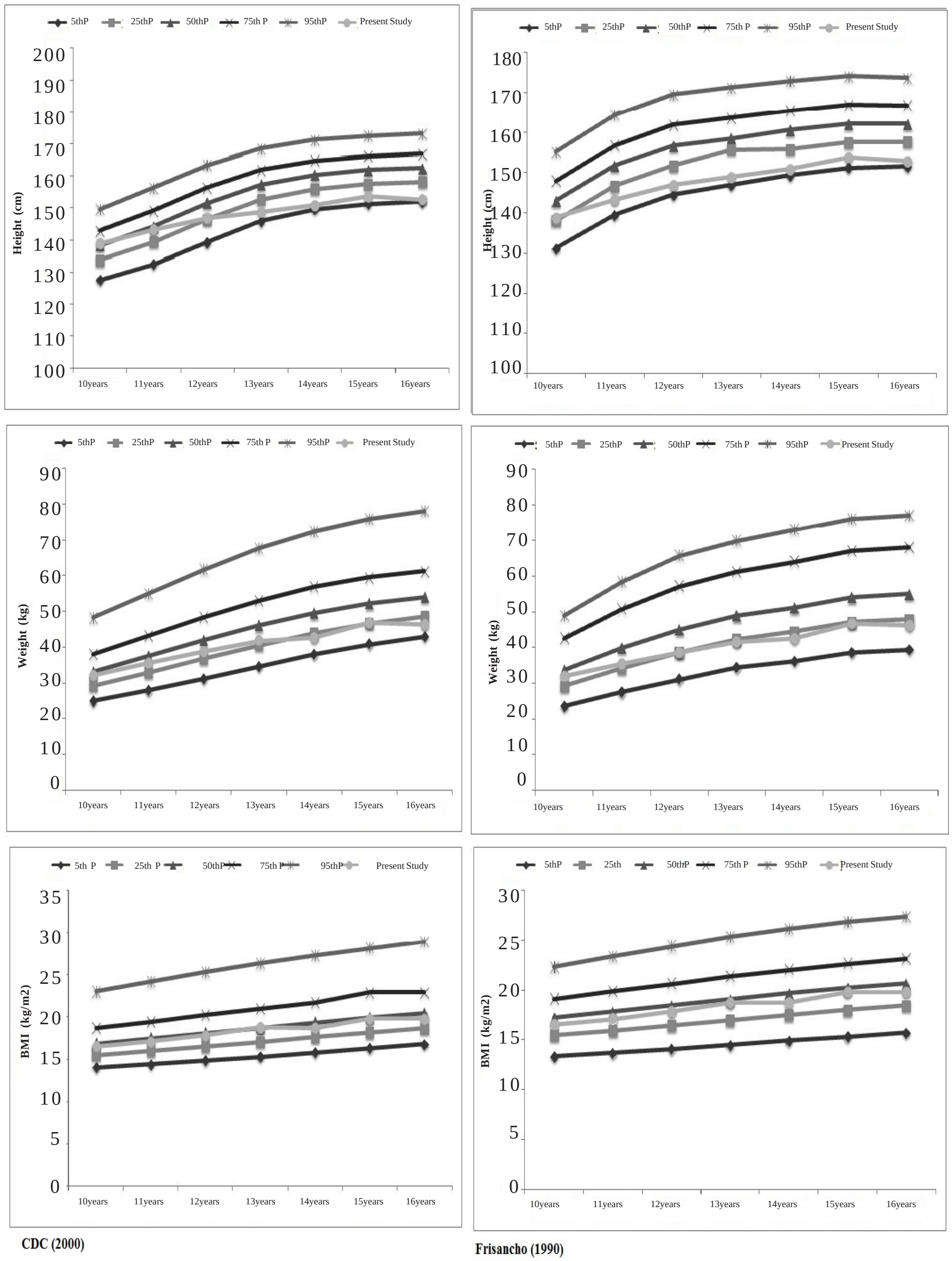

Fig. 1. Age-specific comparison of height, weight and BMI with different growth reference percentiles of the CDC (2000) and US-reference (Frisancho1990) among adolescent girls

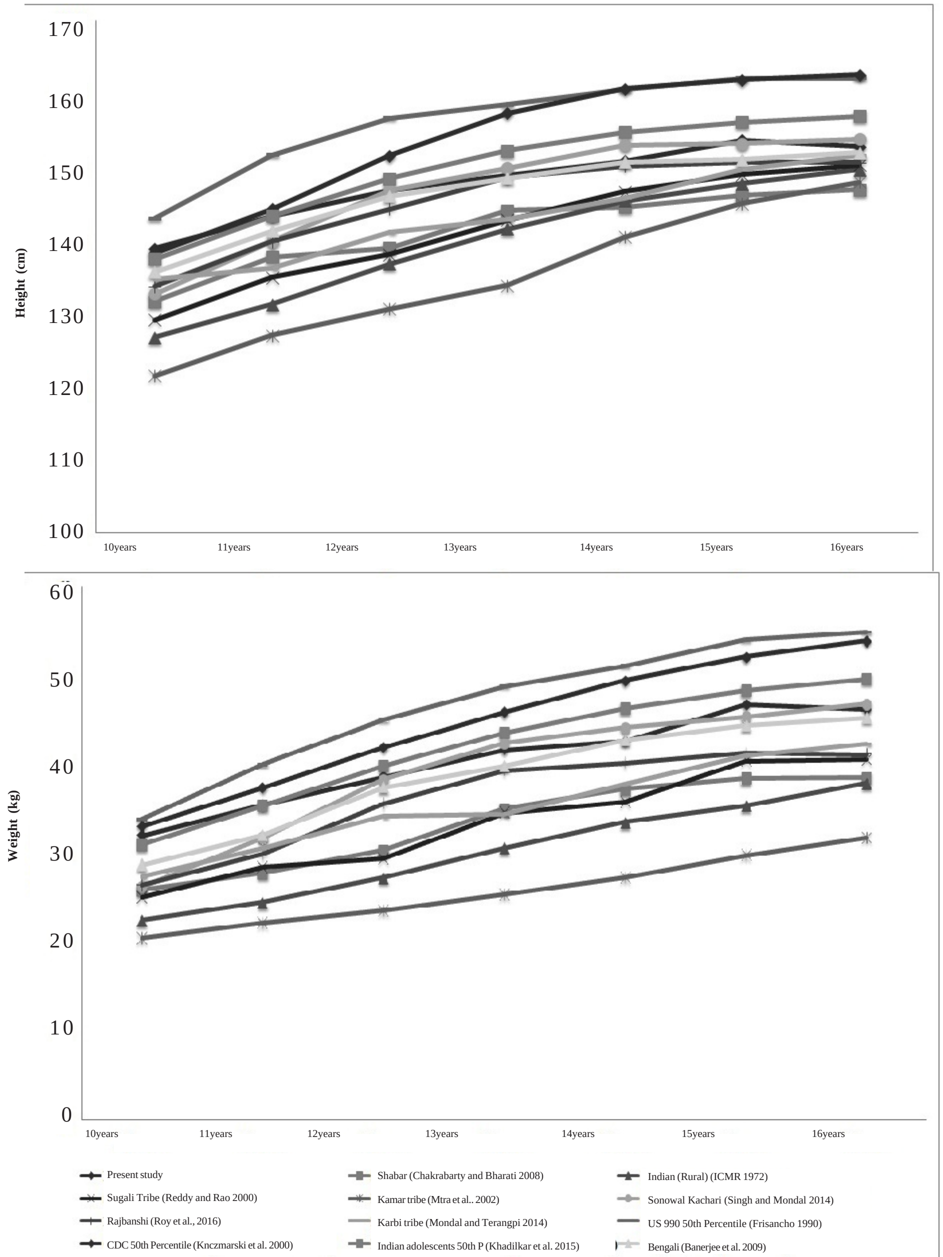

Fig. 2. Age-specific mean height (cm) and weight (cm) comparison of the adolescent girls among Indian adolescents

adolescents (Khadilkar et al. 2015) and Rajbanshi (Roy et al. 2016) (Fig. 2). The age-specific mean height and weight were found higher than most of the Indian adolescents belonging to Kamar (Mitra et al. 2012), Sugalis (Reddy and Rao 2000), Shabar (Chakrabarty and Bharati 2008) and 50th percentile of Indian adolescents (Khadilkar et al. 2015). The adolescence is a period of increased nutritional requirements and a large proportion of the growing children in the developing countries are deprived mainly attributing to poverty, poor socio-economic status, ignorance and lack of awareness and healthcare facilities. This may lead to the nutritional deprivation resulting in the physical growth retardation and can manifest undernutrition in population (Rao et al. 2000; Medhi et al. 2007; Semproli and Gualdi-Russo 2007; Olivieri et al. 2008; Mondal and Sen 2010b; Wells 2010; Sen and Mondal 2013; Singh and Mondal 2014; Rengma et al. 2016; Debnath et al. 2017; Mondal et al. 2017).

Body composition assessment is an important component as distinguishing age/sex and ethnic-specific changes in anthropometric variables of BMI, PBF, FM and FFM occurs with rapid growth changes attributed to the hormonal effect and environment among adolescent girls (Rogol et al. 2002; Wells 2007; Rogol 2010; Chung 2015; Griffiths et al. 2016). The results of the present investigation showed the greater acceleration in body composition (BMI, PBF, FM, UMA, UFA and FFM) among girls as they approach puberty in 11-12 years (Table 1). Excess body adiposity or subcutaneous fat during childhood and adolescents may cause intra-abdominal visceral fat, dyslipidemia, hypertension, insulin resistance, cardio-vascular risk, metabolic syndrome and impaired glucose tolerance (Rodríguez et al. 2004; Staiano and Katzmarzyk 2012; Hafez et al. 2016). The attainment of poor body composition in adolescence is attributed to inadequate or long-term nutritional deprivation during early childhood, prolonged breastfeeding and consumption of low-energy density food (Sen et al. 2010; Singh and Mondal 2014). The results of linear regression analysis showed that BMI and PBF have significant ($p<0.05$) positive association with anthropometric and body composition variables (Tables 4 and 5). Linear regression analysis also showed that FFMI shows the greatest variability for BMI, and SSF shows the greatest variability for PBF ($p<0.05$). The comparison of age-specific mean TSF and SSF values were found $<50^{th}$ percentile of the US-reference (WHO 1995). The UMA and UFA value for the adolescent girls in the present investigation was found below the 25^{th} percentile of US-reference which shows poor body composition among the adolescent girls (Frisancho 1990). The model of nutritional status used in developing countries include the determinants of certain socio-economic status, rural environment, poverty, heavy workload, lesser access to food, healthcare facilities and double burden (Bogin 1998; Dapi et al. 2009; Chatterjee et al. 2009; Mondal and Sen 2010b; Ramachandran 2013; Sen and Mondal 2013; Rengma et al. 2016; Debnath et al. 2017; Sharma et al. 2017). These research investigations reported changes in the physical growth pattern and nutritional status that are attributed to their rural living conditions, food consumption, lack of nutritious food and access to medical/healthcare facilities in population. The attainment of low percentiles of physical growth and body composition measured in anthropometric parameters in early age reflects the adaptive mechanism to the low food intake and the subjects shows compensatory growth during puberty (Eveleth and Tanner 1990; Olivieri et al. 2008). Researchers have also confirmed that physical growth retardation or low-height-for- age/stunting early in life results in an adaptation in energy metabolism that speed up body fat deposition or adiposity and increases the risk of children becoming overweight/obese and likelihood of suffering from the metabolic disorders later in life (Sawaya et al. 2004; Lee et al. 2015).

CONCLUSION

The present investigation provides anthropometric data on physical growth and body composition among rural adolescent girls of Assam, Northeast India. The study revealed that there are significant positive associations between age trend, BMI and PBF with anthropometric and body composition variables, which depends on body adiposity. With the age, muscle-mass and body adiposity changed among adolescent girls. The age-specific variations related among these girls could be attributed to several exogenous factors which may refer to the manifestation in successive generation of population. Lack of awareness about the health and/or nutrition could be a reason behind this problem. In-depth studies are also necessary for identifying the factors responsible for the physical growth retardation and body composition among adolescents. The findings of the present investigation may be attributed to the efficacy of ongoing health and nutritional intervention programme in targeted populations.

RECOMMENDATIONS

The following recommendations are suggested based on the present investigation:

1. The proper nutritional intervention strategies should be planned to improve the physical growth attainment, body composition, nutritional and health status among these adolescent girls.
2. Frequent health checkup camps for the adolescent girls should be conducted by governmental organizations to monitor the physical growth, body composition and health conditions and also to assess the efficacy of existing healthcare facility and intervention programme.
3. The physical growth and body composition evaluation should be integrated into routine epidemiological/clinical practice for the assessment and sequential follow-up of undernutrition.

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