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# Percent of body fat, fat-mass, fat-free mass and assessment of body composition among rural school-going children of Eastern-India

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Abstract: Percent of body fat (PBF), fat mass (FM) and fat free mass (FFM) are useful indicators for the assessment of body composition. The present study was conducted among 1351 children (boys: 660; girls: 691) aged 5–12 years residing in West Bengal, Eastern-India. The children were selected using a stratified random sampling method. Anthropometric measurements of height, weight, triceps skinfold (TSF) and sub-scapular skinfold (SSF) were recorded using standard procedures. The PBF, PBF-for-age z-score (PBFZ) and body mass index (BMI) were subsequently calculated. Body composition was assessed using FM, FFM, fat mass index (FMI) and fat free mass index (FFMI). Age-specific mean values of FM ranged from 2.12–4.00 kg (boys) and 2.16–4.40 kg (girls). Age-specific mean values of FFM ranged from 14.45–23.93 kg (boys) and 14.01–23.03 kg (girls). Sex-specific mean differences between sexes were statistically significant in weight, height, TSF, SSF, PBF, PBFAZ, FM, FFM, FMI and FFMI ($p<0.05$), except in BMI ($p>0.05$). These results are important for future investigations in clinical and epidemiological settings so as to accurately identify the risk of lower or higher adiposity and body composition using PBF, FM and FFM.

Key words: Adiposity, anthropometry, body composition, fat mass, fat free mass, percent of body fat

## Introduction

Body fat is a normal component of human body that accumulates in adipose tissue. It serves as a useful marker for assessing adiposity of individuals (Hu 2008; Sen and Mondal 2013; Colley et al. 2015; Griffiths et al. 2016; Xue et al. 2016). The predictions of body fatness and body composition are based mostly upon anthropometric measures such as height, weight, percentage body fat (PBF), body mass index (BMI), waist-hip ratio and skinfold thickness (Rolland-Cachera 1993; Hall et al. 2007). Although, several sophisticated techniques such as bioelectrical impedance analysis, dual-X-ray absorptiometry, computerized tomography, underwater weighing have also been developed to determine

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body composition (Lee and Gallagher 2008; Duren et al. 2008; Jensen et al. 2016; Andreoli et al. 2016; Gibby et al. 2017; Louer et al. 2017) anthropometric measurements are still widely used to assess the same in many field and epidemiological investigations. As body adiposity proportions vary with age, sex and environmental conditions, it serves as a good indicator of health and nutritional status of children (Rolland-Cachera 1993; Hall et al. 2007; Wells 2007; Sen and Mondal 2013; Reddon et al. 2016; De Onis 2017).

Body composition is most commonly assessed using surrogate anthropometric measures such as BMI, which measures excess adiposity in relation to greater body weight relative to height rather than excess adiposity (Cole et al. 2005; Freedman et al. 2005; Ablove et al. 2015; Hung et al. 2017). However, BMI is unable to differentiate between excess body-weight associated with muscle-mass and/or fat mass (Wells 2010; Thibault et al. 2012; Thibault and Pichard 2012). Moreover, the BMI is a discrete anthropometric measure and can be adjusted according to the body size and body composition (VanItallie et al. 1990; Wells 2010; Griffiths et al. 2016; Alpizar et al. 2017). BMI can be better expressed in terms of fat mass (FM) and fat free mass (FFM) [BMI = FFM (kg)/height$^2$ (m$^2$) + FM (kg)/height$^2$ (m$^2$)] (Wells 2010) and it also includes the FM index (FMI) and FFM index (FFMI). The disintegration of BMI into FM and FFM needs the help of anthropometric measurements and body composition assessment (VanItallie et al. 1990; Wells 2010; Sen and Mondal 2013; Xue et al. 2016; Sharma and Mondal 2018). Body composition status reflects nutritional intakes, losses and needs over time (i.e., FFM and FFMI) along with the prevalence of undernutrition. According to some researchers, FM and FFM have the advantage of providing discrete measures for these two components of weight, each adjusted for an independent component of size, although in some cases a more complex approach is required (Wells 2007; Wells 2010; Sen and Mondal 2013). A few research studies have used FM, FFM, FMI and FFMI to assess body composition and adiposity level of children and adults (Musaiger and Gregory 2000; Freedman et al. 2005; Gültekin et al. 2005; Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Ghosh et al. 2009; Sen and Mondal 2013; Sharma and Mondal 2018).

Percent of body fat (PBF) is considered to be a relatively better measure of excess adiposity or obesity. The overall adiposity level is estimated by PBF mainly in epidemiological settings and studies have reported a significant relationship between PBF and BMI when sex and age are taken into account (Slaughter et al. 1988; Gallagher et al. 1996; Ablove et al. 2015; Ho-Pham et al. 2015; González-Agüero et al. 2017). The skinfold thickness (e.g. triceps and/or sub-scapular) are also now widely used to determine body adiposity (e.g., PBF and FM) using the standard equations (Slaughter et al. 1988; VanItallie et al. 1990; Rolland-Cachera 1993; Wells 2007; González-Agüero et al. 2017). Excess body adiposity have significant relationship with the occurrence of several preventable non-communicable diseases (e.g., cardiovascular disease, insulin resistance, diabetes mellitus, dyslipidaemia and certain types of cancer) and related mortality and morbidities. Several researchers have subsequently reported the widespread use and importance of using PBF, FM, FFM, FMI and FFMI as indicators of body adiposity (Slaughter et al. 1988; VanItallie et al. 1990; Rolland-Cachera 1993; Musaiger and Gregory 2000; Freedman et al. 2005; Gültekin et al. 2005; Freedman et al. 2005; Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Wells 2007; Ghosh et al. 2009; Sen and Mondal 2013; Sharma and Mondal 2018). Several studies have also highlighted the important relationship between undernutrition and body composition among various vulnerable segments of the population in India (Bose et al. 2007; Kshatriya and Ghosh 2008; Datta Banik 2011; Sen and Mondal 2013; Singh and Mondal 2014; Datta Banik and Das 2015; Debnath et al. 2017; Sharma and Mondal, 2018). Hence, assessment of body composition is becoming imperative among the large sized, poverty stricken and nutritionally vulnerable segments of the Indian populations. Given the above, the present study aims to assess age-sex specific adiposity levels and body composition of rural school-going children using PBF, FM, FFM, FMI and FFMI so as to assess their nutritional status.

## Materials and methods

The present school based cross-sectional study was conducted among 1351 school going children (boys: 660; girls: 691) aged 5-12 years residing in Phansidewa Block of the Darjeeling district of West Bengal, India. This block (Latitude 26° 34´59´´N, Longitude 88° 22´00´´E) covers an area of 308.65 km$^2$ and has a total population of 171,508 individuals (males: 87,945; females: 83,563) with a literacy rate of 41.59% (males: 51.85%; females: 30.80%) (Census of India 2011). The region is situated near the Indo Bangladesh border region and ~35–40 km from the sub-divisional town of Siliguri. The residents of the block have access to all the basic amenities, such as hospitals, schools, post office, markets and government offices (Mondal and Sen 2010; Sen and Mondal 2013; Debnath et al. 2018).

The children were residing in and around the block-level town of Phansidewa, located in the above-mentioned block. They were the students of 12 primary schools covered under the block. The schools were selected on the basis of identical student strengths and road accessibility. The children were selected using a stratified random sampling method. Initially 1477 children (boys: 746; girls: 731) in the age group of 5-12 years were identified and approached to participate in the study. Their dates of birth were checked from the school record and the birth certificates issued by the Government. Socio-economic status (SES) of the children was evaluated using a modified version of the scale of Kuppuswamy’s (Mishra and Singh 2003; Kumar et al. 2007). This scale allows determination of SES based on a score calculated from education, occupation and monthly income. Of these 1477 children, 126 of them (boys: 86; girls: 40) were excluded from the study as their dates of birth were either not available or they were not in the age group of 5-12 years or they did not belong to the same SES. So the final sample consisted of 1351 (boy: 660; girls: 691) aged 5-12 years belonging to the same SES (in this case: lower SES) based on the modified scale of Kuppuswamy. All the children were free from any previous histories related to medical and surgical episodes, physical deformity and were not suffering from any diseases at the time of collecting the data. The parents of the children were informed about the objectives of the study prior to data collection. An informed consent was obtained from them and participation in the study was purely voluntary. The study was conducted in accordance with the ethical guidelines for human experiments, as laid down the Helsinki Declaration of 2000 (Touitou et al. 2004). The data were collected during the period from September 2015 to March 2016.

### Anthropometric measurements collected

Anthropometric measurements of height, weight, triceps (TSF) and sub-scapular (SSF) skin-folds were recorded using standard anthropometric procedures. Height of the children was recorded to the nearest 0.1 cm using an anthropometer rod with the head held in the Frankfort horizontal plane. Weight of the children, wearing minimum clothing and with bare feet, was taken using a portable weighing scale to the nearest 100 gm. The skinfold measurements of TSF and SSF were measured using a Holtain skinfold calliper on the right side of each child to the nearest to 0.2 mm. The skinfold calliper was calibrated to exert a constant pressure of 10 $gm/mm^2$. The children were measured with ample care and precision to avoid any possible human error in the process of data collection.

The intra-observer and inter-observer technical errors of measurements (TEM) were calculated to determine the accuracy of the measurements using the standard procedure of Ulijaszek and Kerr (1999). The TEM was calculated using the following equation:

$TEM=\sqrt{(\Sigma D^2/2N)}$, [D=difference between the measurements, N=number of individuals].

The co-efficient of reliability (R) was subsequently calculated from TEM using the following equation:

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

For calculating TEM, height, weight, TSF and SSF were recorded by two of the authors (SD and NM) from 50 children aged 5-12 years other than those selected for the study. Very high values of R (>0.975) were obtained for height and weight. The values were observed to be within the acceptable limits of 0.95 as recommended by Ulijaszek and Kerr (1999). Hence, the measurements recorded by SD and NM were considered to be reliable and reproducible. All the measurements in the course of the present study were subsequently recorded by one of the authors (SD). Care was taken to avoid any possible systematic errors (instrumental or definition of landmarks) in the course of recording the anthropometric measurements as outlined by Harris and Smith (2009).

### Assessment of body composition

The following equations of Slaughter et al. (1988) were used to estimate PBF:

$\text{Boys} = 1.21\,(TSF + SSF) - 0.008\,(TSF + SSF)^2 - 1.7$

$\text{Girls} = 1.33\,(TSF + SSF) - 0.013\,(TSF + SSF)^2 - 2.5$

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

$FM\ (kg) = (PBF/100) \times \text{weight}\ (kg)$

$FFM\ (kg) = \text{Weight}\ (kg) - FM\ (kg)$

$FMI\ (kg/m^2) = FM/\text{Height}^2\ (m^2)$

$FFMI\ (kg/m^2) = FFM/\text{Height}^2\ (m^2)$.

The BMI was calculated to assess the body composition characteristics of the children using the following standard equation:

BMI ($kg/m^2$) = Weight (kg)/$Height^2$ ($m^2$).

The age and sex-specific PBF-for-age z-score (PBFAZ) was calculated using the following equation:

Z-score = {(X/M)*L –1}/(L*S)

where X=PBF, L, M and S are the age-sex specific values of the appropriate table corresponding reference populations.

The recently proposed L, M, and S age-sex specific reference values using the National Health and Nutrition Examination Survey (NHANES) conducted by the National Centre for Health Statistics data were used to calculate the age and sex-specific z-scores among children (Laurson et al. 2011).

### Statistical Analysis

The data were statistically analyzed using the Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL; version 17.0). A p-value of less than 0.05 and 0.01 was considered to be statistically significant. Independent sample t-test was done to assess sex-specific mean differences in the anthropometric variables. One-way analysis of variance (ANOVA) using the Scheffe procedure was done to assess age-specific mean differences in the anthropometric and body composition variables. Two-way ANOVA was used to control the influence of age and sex on the body composition variables (e.g., BMI, PBF, FM, FFM, FMI and FFMI). The LMS model approach was utilized to convert the measurements for a child of known age and sex to evaluate the centile and standard deviation score or z-score, as proposed by Cole and Green (1992) and Cole et al. (1998). This method was used to derive the age- and sex-specific percentile reference curves of BMI, FM and FFM. The LMS Chart Maker software program (The Institute of Child Health, London) was used to obtain the smooth centile curves that fitted smooth centile curves to the reference data. The method summarizes percentiles at each age based on the power of age-specific Box-Cox power transformations used to normalize data. The centile curves (3rd, 10th, 25th, 50th, 75th, 90th and 97th) were derived as reference data for further evaluation of body composition.

## Results

The age-sex specific subject distribution and the means (±standard deviations) of the anthropometric and body composition variables among rural school going children are presented in Table 1.

Age-specific mean values of weight, height and FFM were observed to progressively increase with age among both boys and girls. Boys were observed to be heavier than girls with exceptions in the ages of 7 years. The skinfold measurements of TSF, SSF, BMI, PBF, FMI and FFMI did not exhibit any noteworthy age and sex-specific trend among the children. The age-specific mean skinfold thickness (e.g., TSF and SSF) values were observed to be significantly higher among girls compared to boys ($p<0.01$). The age-specific mean value of TSF was higher at the age of 10 years (8.72 mm) and 10 years (9.61 mm) and lowest in 8 years (7.17 mm) and 12 years (8.68 mm) among boys and girls, respectively.

Table 1. Age-specific descriptive statistics: means and standard deviation (in parenthesis) of the anthropometric variables in children

| Age (years) | Sample size | | Height (cm) | | Weight (kg) | | TSF (mm) | | SSF (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| 5 | 61 | 62 | 108.28 (6.47) | 108.26 (5.30) | 16.58 (2.69) | 16.17 (1.86) | 8.03 (2.21) | 8.74 (1.80) | 4.93 (1.82) | 5.07 (1.01) |
| 6 | 72 | 91 | 111.77 (6.00) | 111.05 (6.00) | 17.71 (2.54) | 16.70 (2.31) | 7.64 (1.81) | 8.31 (1.78) | 4.82 (0.83) | 5.29 (1.24) |
| 7 | 98 | 104 | 115.72 (6.59) | 117.15 (4.87) | 19.11 (2.82) | 19.19 (2.17) | 7.40 (1.68) | 8.36 (2.03) | 4.88 (0.97) | 5.53 (1.30) |
| 8 | 92 | 105 | 122.09 (6.77) | 120.87 (5.30) | 20.95 (2.99) | 20.55 (2.75) | 7.17 (2.00) | 8.22 (2.11) | 5.02 (1.13) | 5.91 (1.71) |
| 9 | 117 | 122 | 127.09 (5.54) | 126.01 (5.90) | 23.04 (3.08) | 22.83 (3.91) | 7.50 (2.86) | 9.02 (2.98) | 5.42 (1.86) | 6.36 (2.27) |
| 10 | 93 | 100 | 130.45 (6.09) | 130.56 (6.89) | 26.13 (5.29) | 26.08 (9.91) | 8.72 (3.95) | 9.61 (2.44) | 6.40 (4.27) | 7.01 (1.97) |
| 11 | 83 | 75 | 134.49 (6.24) | 134.00 (6.08) | 27.66 (5.03) | 27.43 (4.79) | 7.76 (2.79) | 9.51 (2.97) | 5.73 (2.55) | 7.02 (2.68) |
| 12 | 44 | 32 | 135.41 (6.86) | 131.95 (10.01) | 27.05 (4.08) | 25.89 (5.23) | 7.68 (1.83) | 8.68 (2.00) | 5.51 (1.15) | 6.24 (2.02) |
| Total | 660 | 691 | 123.25 (10.88) | 122.13 (10.32) | 22.27 (5.29) | 21.65 (6.15) | 7.72 (2.61) | 8.81 (2.41) | 5.36 (2.24) | 6.07 (1.96) |
| *F*-value | | | 190.30 | 188.50 | 98.83 | 60.78 | 3.07 | 4.79 | 5.33 | 13.23 |
| *p*-value | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

| Age (years) | Sample size | | BMI (kg/m²) | | PBF (%) | | PBFZ | | FM (kg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| 5 | 61 | 62 | 14.12 (1.67) | 13.80 (1.15) | 12.52 (3.36) | 13.07 (2.43) | -0.56 (0.81) | -0.64 (0.73) | 2.12 (1.04) | 2.16 (0.51) |
| 6 | 72 | 91 | 14.14 (1.31) | 13.56 (1.38) | 12.09 (2.40) | 13.10 (2.52) | -0.61 (0.63) | -0.81 (0.72) | 2.17 (0.71) | 2.21 (0.61) |
| 7 | 98 | 104 | 14.23 (1.44) | 13.97 (1.33) | 11.91 (2.33) | 13.36 (2.85) | -0.69 (0.60) | -0.89 (0.79) | 2.30 (0.66) | 2.58 (0.69) |
| 8 | 92 | 105 | 14.02 (1.22) | 14.03 (1.30) | 11.79 (2.90) | 13.55 (3.12) | -0.89 (0.72) | -1.04 (0.80) | 2.50 (0.86) | 2.83 (0.97) |
| 9 | 117 | 122 | 14.24 (1.56) | 14.30 (1.61) | 12.45 (3.86) | 14.57 (3.96) | -0.91 (0.70) | -1.04 (0.82) | 2.94 (1.35) | 3.43 (1.56) |
| 10 | 93 | 100 | 15.26 (2.20) | 15.35 (6.94) | 14.27 (6.30) | 15.80 (3.55) | -0.78 (0.81) | -0.95 (0.75) | 4.00 (3.07) | 4.16 (1.77) |
| 11 | 83 | 75 | 15.21 (1.76) | 15.20 (1.83) | 12.96 (4.37) | 15.56 (4.22) | -0.29 (0.55) | -1.19 (0.80) | 3.73 (2.31) | 4.40 (1.96) |
| 12 | 44 | 32 | 14.67 (1.16) | 14.73 (1.61) | 12.81 (2.59) | 14.28 (3.11) | -0.88 (0.47) | -1.56 (0.63) | 3.50 (1.03) | 3.77 (1.43) |
| Total | 660 | 691 | 14.48 (1.66) | 14.32 (3.06) | 12. 59 (3.90) | 14.20 (3.45) | -0.64 (0.77) | -0.98 (0.79) | 2.91 (1.78) | 3.16 (1.51) |
| *F*-value | | | 8.46 | 4.41 | 3.90 | 8.94 | 28.47 | 6.14 | 16.38 | 36.42 |
| *p*-value | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Abbreviations: TSF – triceps skinfold; SSF - sub-scapular skinfold; BMI – body mass index; PBF – percent of body fat; PBFZ – percent of body fat for-age z-score; FMI - fat mass index; FFMI - fat free mass index

Table 1. Age-specific descriptive statistics: means and standard deviation (in parenthesis) of the anthropometric variables in children

| Age (years) | Sample size | | FFM (kg) | | FMI (kg/m²) | | FFMI (kg/m²) | |
|---|---|---|---|---|---|---|---|---|
| | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| 5 | 61 | 62 | 14.45 (1.96) | 14.01 (1.61) | 1.81 (0.76) | 1.84 (0.43) | 12.31 (1.14) | 11.94 (0.86) |
| 6 | 72 | 91 | 15.54 (2.03) | 14.54 (1.92) | 1.72 (0.45) | 1.79 (0.47) | 12.42 (1.07) | 11.77 (1.10) |
| 7 | 98 | 104 | 16.81 (2.37) | 16.61 (1.80) | 1.71 (0.44) | 1.88 (0.49) | 12.52 (1.18) | 12.10 (1.08) |
| 8 | 92 | 105 | 18.44 (2.43) | 17.72 (2.08) | 1.67 (0.50) | 1.93 (0.60) | 12.35 (0.96) | 12.10 (0.88) |
| 9 | 117 | 122 | 20.10 (2.24) | 19.40 (2.67) | 1.81 (0.77) | 2.13 (0.84) | 12.44 (1.14) | 12.17 (1.01) |
| 10 | 93 | 100 | 22.13 (2.83) | 21.92 (8.49) | 2.30 (1.56) | 2.44 (1.11) | 12.97 (1.00) | 12.91 (6.00) |
| 11 | 83 | 75 | 23.93 (3.30) | 23.03 (3.28) | 2.03 (1.04) | 2.42 (0.97) | 13.18 (1.06) | 12.78 (1.13) |
| 12 | 44 | 32 | 23.54 (3.36) | 22.12 (4.16) | 1.89 (0.46) | 2.12 (0.64) | 12.78 (0.97) | 12.61 (1.25) |
| Total | 660 | 691 | 19.36 (4.05) | 18.49 (4.95) | 1.87 (0.88) | 2.07 (0.78) | 12.61 (1.11) | 12.27 (2.50) |
| *F*-value | | | 141.10 | 58.32 | 5.33 | 10.04 | 7.30 | 2.33 |
| *p*-value | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.05 |

Abbreviations: TSF – triceps skinfold; SSF - sub-scapular skinfold; BMI – body mass index; PBF – percent of body fat; PBFZ – percent of body fat for-age z-score; FMI - fat mass index; FFMI - fat free mass index

The age-specific mean value of SSF was ranged 4.82 mm (in 6 years) to 6.40 mm (in 10 years) and 5.07 mm (in 5 years) to 7.02 (in 11 years) among boys and girls, respectively. Age-specific mean BMI values were observed to be slightly higher among boys than girls, especially in the early ages (e.g., 5–7 years), but observed to be markedly higher among girls in the older age groups (e.g., 9, 10 and 12 years). The age-specific mean BMI values ranged from 14.12 kg/m² (in 5 years) to 15.26 kg/m² (in 10 years) and 13.56 kg/m² (in 6 years) to 15.35 kg/m² (in 10 years) among boys and girls, respectively. The age-specific means PBF and PBFAZ values did not show any uniform increase in age among the children. Mean PBF was observed to be higher in 10 years (14.27%) and lowest in 8 years (11.79%) among boys and highest in 10 years (15.80%) and lowest in 5 years (13.07%) among girls. The age-specific mean value of PBFAZ was ranged 0.29 (in 11 years) to −0.89 (in 8 years) and −0.64 (in 5 years) to −1.56 (in 12 years) among boys and girls, respectively.

The mean values in fat pattern indices of FM and FFM gradually increased with advancement of age among the children but exceptions were observed in 11-12 years (in boys) and 12 years (in girls). Age-specific mean FM and FMI were observed to be higher among girls than boys ($p<0.05$), but a reverse trend was observed in FFM and FFMI ($p<0.05$). Age-specific mean values of FM and FFM ranged from 2.12–4.00 kg (in boys) and from 2.16–4.16 kg (in girls) and from 14.45–23.92 kg (in boys) and from 14.01–23.03 kg (in girls), respectively (Table 1). Age-specific mean values of FMI and FFMI did not exhibit any age-specific trend among boys and girls. The age-sex specific mean FMI values were ranged 1.67 -2.30 kg/m$^2$ (in boys) and 1.79 -2.44 kg/m$^2$ (in girls). Similarly, the age-sex specific mean FFMI values were ranged 12.31 kg/m$^2$ (in 5 years) to 13.18 kg/m$^2$ (in 11 years) and 11.77 kg/m$^2$ (in 6 years) to 12.91 kg/m$^2$ (in 10 years) among boys and girls, respectively. The existence of significant sex differences indicates that these body composition indicators reflecting the sexual dimorphism in PBF, FM, FFM, FMI and FFMI ($p<0.05$). Age- and sex-specific smooth percentile curves for PBF, FM and FFM derived from further evaluation of body composition using L, M and S parameters

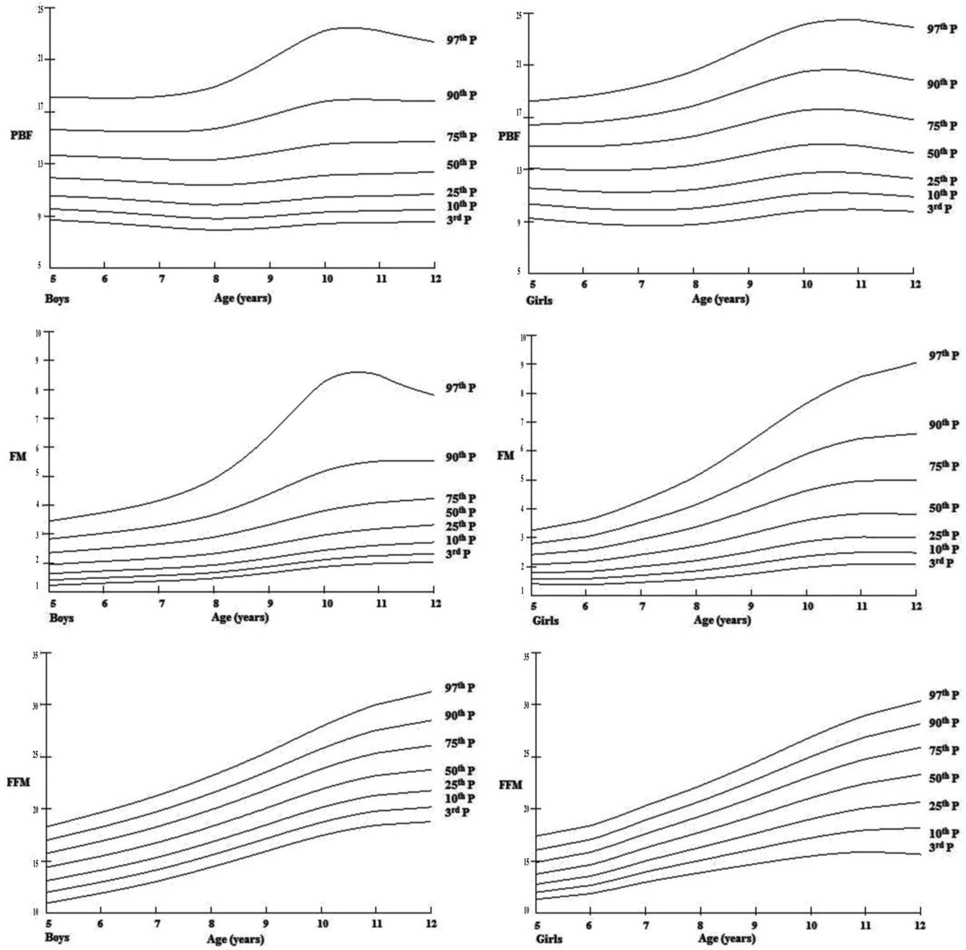


Figure 1: Age-sex specific smooth percentile curves of PBF, FM and FFM using LMS model.

in the model approach statistical procedures among the rural school-going children are presented in Figure 1. Age- and sex-specific selected percentile of 5th, 10th, 25th, 50th, 75th, 90th and 95th values for PBF, UMA and UFA were derived separately among rural school-going boys and girls and shown in Figure 1.

Using independent sample t-test, there were statistically significant sex differences ($p<0.05$) in anthropometric and body composition indicators of weight (t-value= 2.03), height (t-value= 2.02), TSF (t-value= −7.91), SSF (t-value= −6.24), PBF (t-value= −7.98), FM (t-value= −2.80), FFM (t-value= 3.59), FMI (t-value= −4.42) and FFMI (t-value= 3.27) except in BMI (t-value= 1.25) (not significant). Using ANOVA, differences in anthropometric and body composition variables were also observed to be statistically significant ($p<0.05$) with respect to age and weight, height, TSF, SSF, BMI, PBF, PBFAZ, FM. FFM, FMI and FFMI among boys and girls (Table 1). The results of two way ANOVA showed statistically insignificant association for the anthropometric and body composition variables of height, weight, BMI, PBF, TSF, SSF, FM, FFM, FMI and FFMI except in PBFZ ($p<0.001$) with respect to age and sex (Table 2).

## Discussion

The amount and distribution of body adiposity (e.g., FM) and composition of muscularity (e.g., lean mass or FFM) are now understood to be important health outcomes in body composition assessment in infants and children (Wells and Fewtrell 2006; Thibault and Pichard 2012; Aguirre et al. 2015; Boone-Heinonen et al. 2015; Simmonds et al. 2015; Santos et al. 2016; González-Agüero et al. 2017; Sharma and Mondal 2018). Studies have reported marked sexual dimorphism in the relationship of visceral and peripheral adiposity (Wells 2007; Shen et al. 2009; Nedungadi and Clegg 2009; Pausova et al. 2012; Sen and Mondal 2013; Crocker et al. 2014; Singh and Mondal, 2014; Whitaker et al. 2016; Debnath et al. 2017). But the differences in adiposity distributions are evident during early childhood with differences in total body adiposity onset before puberty

Table 2. Two-way analysis of variance (ANOVA) of the age and sex specific anthropometric variables

| Age* Sex specific effect | F-value | d.f. | *p*-value |
|---|---|---|---|
| Height | 1.59 | 1,1350 | 0.13 |
| Weight | 0.33 | 1,1350 | 0.94 |
| BMI | 0.41 | 1,1350 | 0.89 |
| PBF | 1.17 | 1,1350 | 0.32 |
| TSF | 0.78 | 1,1350 | 0.60 |
| SSF | 1.07 | 1,1350 | 0.38 |
| FM | 0.93 | 1,1350 | 0.48 |
| FFM | 0.51 | 1,1350 | 0.83 |
| FMI | 1.01 | 1,1350 | 0.42 |
| FFMI | 0.35 | 1,1350 | 0.93 |
| PBFZ | 17.08 | 1,1350 | 0.00 |

(He et al. 2002; Staiano et al. 2013). The term 'mini puberty of early infancy' has been used for the sex-related divergence in adipose tissue distribution observed may be mediated by the hormonal fluctuations (Leung et al. 2004). Studies have attributed to such adiposity differences caused due to major hormonal (i.e., sex steroid) changes during puberty (Wells 2007; Correia-Costa et al. 2015).

Several studies have already validated different skinfold equations with alternate methods of estimation and recommended the use of the equations of Slaughter et al. (1988) for the evaluation of body fat among pre-pubertal children (Goran et al. 1996; Boot et al. 1997; Laurson et al. 2011; Sen and Mondal 2013; Almeida et al. 2016; González-Agüero et al. 2017). The present study evaluated PBF content in order to evaluate the body composition characteristics of rural school-going children using the equation of Slaughter et al. (1988). Furthermore, several studies have assessed body composition characteristics in children utilizing these equations for estimation of PBF among children from both non-Indian (Musaiger and Gregory 2000; Gültekin et al. 2005; Ghosh et al. 2009; Laurson et al. 2011; Aguirre et al. 2015; Noradilah et al. 2016; González-Agüero et al. 2017) and Indian ethnic populations (Mukhopadhyay et al. 2005; Chowdhury et al. 2007; Sen and Mondal 2013; Sharma and Mondal 2018). The results indicated pronounced sexual differences in adiposity and body composition measures (e.g., PBF, FM, FM, FMI and FFMI) between boys and girls ($p<0.01$). Similar trends of body composition and adiposity indicators were reported among Indian (Gerver et al. 2000; Sen and Mondal 2013) and rural Chinese (Wang et al. 2007) children. The differences in adiposity measures (PBF, FM and FFM) were also observed to be more prominent with the advancement of age (Table 1). The sex-specific mean values were greater in girls than boys but were distinctly higher in older age groups (e.g. 9–12 years) ($p<0.05$). The changes in body composition characteristics among girls have been observed in the present study, especially when they approached the stage of puberty. Wells (Wells 2007) advocated that sexual dimorphism of body composition is evident from fetal life, but emerges primarily during puberty and such differences in body composition are primarily attributed to the action of steroidal hormones. Sex steroid hormones (e.g., testosterone and oestrogen) play an important role in the distribution and accumulation of adipose tissue in abdomen and gluteofemoral regions, respectively (Norgan 1997; Lee and Fried 2017), which contributes critically to the sex differences in adiposity fat distribution during puberty (Gültekin et al. 2005; Wells 2010; Guo et al. 2016; Lee and Fried 2017). Moreover, testosterone is an important factor for the increase in lean mass or FFM (in boys) and oestrogen strongly influence the increased fatness or FM (in girls) which leads to the sex differences in body fatness (Wells 2007, 2010; Glass et al. 2016; Lee and Fried 2017). Several studies have reported that fatness showed stability between early infancy and childhood and sex differences appear in body composition prior to the onset of sexual maturation (Gerver et al. 2000; Wells 2010; Sen and Mondal 2013; Crocker et al. 2014; Breij et al. 2017; Halfon et al. 2018). Genetic effects on sex-specific differences on body fat deposition and distribution have been observed from fetal life and become more prominent from puberty and this difference decrease steadily with age and become almost similar in adulthood (Wells 2007, 2010; Sen and Mondal 2013; Crocker et al. 2014). In case of males lesser amount of deposited body adiposity and it remains allocated primarily in the abdomen but in females adipose tissue accumulation is observed to be almost double and mostly found in the lower body and breasts (Blouin et al. 2008; Wells 2010; Guo et al. 2016; Lee and Fried 2017). The present study also showed that girls were observed to have higher body fat levels than their male counterparts in connection with adiposity indicators (e.g., TSF, SSF, PBF, FM and FMI). Several studies have already used these equations to assess the PBF, FM, FFM, FMI and FFMI among children (Chowdhury et al. 2007; Ghosh et al. 2009; Sen and Mondal 2013; Almeida et al. 2016; González-Agüero et al. 2017; Sharma and Mondal 2018). It has been reported that the Tanner stages had a significant relationship with body composition in both sexes and were significantly positively related to lean tissue mass and bone mineral content among boys and girls and to PBF and FM in girls in the higher age groups (Boot et al. 1997). Differences in adiposity patterns have also been reported among Santhal (Chowdhury et al. 2007), Nepalese (Ghosh et al. 2009), Indian (Gerver et al. 2000), Chinese (Wang et al. 2007) and Dutch children (Weststrate et al. 1989). Age-specific FM values observed in the present study were higher than those obtained from Nepalese children (Ghosh et al. 2009). FFM-for-age values were lower than those reported for Bahraini (Musaiger and Gregory 2000), Turkish (Gültekin et al. 2005), Santhal (Chowdhury et al. 2007) and Nepalese children (Ghosh et al. 2009). The age-specific percentile values were almost similar in the 95th percentile, 75th percentile and 50$^{th}$ percentile to Turkish (Gültekin et al. 2005), Santhal (Chowdhury et al. 2007) and Nepalese children (Ghosh et al. 2009), respectively. Similar results have been reported by some other studies (Chowdhury et al. 2007; Ghosh et al. 2009; Guo et al. 2016). It has now been suggested that, due to the limitation of expressing body composition data as kilograms (e.g. kg of FM and FFM) and as percentages (e.g. PBF), the FMI (kg of FM/ height$^2$) and FFM (kg of FFM/ height$^2$) appear to be better indicators of body composition (Freedman et al. 2005). While the FMI relates fat mass to height, the FFMI estimates muscle mass related to height. The age-specific mean values of FMI and FFMI among the rural school going children were lower than the reported values of Eckhardt et al. (2003). The indices of FFMI and FMI therefore offer a powerful framework for evaluating within and between-population variability in body composition and address physique (FFMI) as well as relative adiposity (FMI). The ethnic variation might be attributed to genetic adaptations to ancestral environment and exposure to more contemporary ecological stresses, as it has been reported that variations in PBF, FM, FFM, FMI and FFMI between populations could be to their ethnic elements (Musaiger and Gregory 2000; Wells 2010; Sen and Mondal 2013).

## Conclusion

The present study recommends the evaluation of body composition to improve screening for undernutrition in hospitalized patients and in field and clinical settings in order to reduce chronic undernutrition related mortality and morbidity. The findings of the present study are important in providing more insight for future investigations in the field and large epidemiological settings so as to accurately identify risk of lower or higher adiposity status and propose a major opportunity to improve through proper intervention programmes.


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## Authors' contributions

SD, NM and JS have equally contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the manuscript and revising it critically for important intellectual content and the final approval of the version to being submitted.

## Conflict of interest

There is no conflict of interests regarding publication of this paper.

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