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Use of upper arm anthropometry, upper arm muscle area-by-height (UAMAH) and mid-upper-arm-circumference (MUAC)-for-height as indicators of body composition and nutritional status among children

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ABSTRACT: Upper arm anthropometry has a potential role to provide useful estimations of body composition and nutritional status. Aims of the present cross-sectional study were to assess body composition and nutritional status of rural school-going children using upper arm anthropometric measures such as upper arm muscle area-by-height (UAMAH) and mid-upper arm circumference (MUAC) for-height. The present cross-sectional study was conducted among 1281 children of West Bengal, India (boys 619, girls 662) aged 5–12 years and selected using a stratified random sampling method. Anthropometric measurements of height, weight, MUAC and triceps skinfold (TSF) were recorded. Body composition and nutritional status were assessed using upper arm muscle area (UMA), upper arm fat area (UFA), UAMAH and MUAC-for-height. Age-sex-specific overall adiposity in TSF, UFA, arm fat index and upper-arm fat area estimates were higher among girls than boys ($p<0.01$), but UMA and upper-arm muscle area estimates were observed to be higher among boys than girls ($p<0.05$). High prevalence of undernutrition was found among both boys (53.15%) and girls (41.69%) using UAMAH ($p<0.01$). The overall prevalence of low MUAC-for-height was higher among boys (28.59%) than girls (25.68%) ($p>0.05$). Upper arm anthropometric measures, UAMAH and MUAC-for-height are useful for assessment of body composition and nutritional status among children.

KEY WORDS: anthropometry, upper arm composition, undernutrition, upper arm muscle area-for-height, mid-upper arm circumference-for-height, body composition

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Introduction

Body composition is strongly associated with nutritional status, diet and physical activity, sex and disease prevalence. Its determination allows for the quantitative assessment of muscle mass and body adiposity changes that in turn reflect nutritional intake, diseases, morbidity and losses and expenses over a period of time (Thibault et al. 2012; Sen and Mondal 2013). Changes in body composition are potentially important in both clinical and epidemiological investigations. As poor body composition and low nutritional status can lead to increased morbidity, decreased physical activity and performance, evaluation of body composition of the nutritionally vulnerable segments of a population becomes priority for researchers (Thibault and Pichard 2012; Thibault et al. 2012). Anthropometry is the traditional technique of choice for researchers to assess body composition and nutritional status. It is only in the last couple of decades that new techniques have been developed to understand body size and shape, biology of human adipose tissue and its estimation and distribution (Wells 2010; Thibault and Pichard 2012; Thibault et al. 2012; Sen and Mondal 2013). These methods include under-water weighing, air displacement plethysmography, bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DEXA) (Sun et al. 2003; Kontogianni et al. 2005; Sala et al. 2007; Wells 2010). A major difficulty in the interpretation of body composition analysis is that different methods may yield different results for the same variable in the same individual. However, assessment of body composition, based on anthropometric measurements still remains an important method of choice in epidemiologic, field and clinical studies at both individual and/or population levels (Rolland-Cachera 1993; Wells 2001; Gibson 2005; Hall et al. 2007).

Body composition and nutritional status of children have been routinely assessed utilizing anthropometry. The measurements that are usually utilized are height, weight, mid- upper arm circumference (MUAC) and skinfold thickness (e.g., triceps and sub-scapular) (Frisancho 1974, 1989; Rolland-Cachera 1993; Gibson 2005; Hall et al. 2007). Using these anthropometric measurements, a considerable number of epidemiological investigations have been conducted to assess body composition and undernutrition among children (e.g., Gültekin et al. 2006; Chowdhury et al. 2007; Chowdhury and Ghosh 2009; Sen et al. 2011; Sen and Mondal 2013; Sen et al. 2015). Studies have also pointed to the fact that body composition and nutritional status were affected by a number of socio-economic variables (Sen et al. 2011, 2015; Sen and Mondal 2013; Singh and Mondal 2014; Rengma et al. 2016). Upper arm anthropometry is composed of upper arm muscle area (UMA), total upper arm area (TUA), upper arm fat area (UFA), arm fat index (AFI), upper arm fat area estimate (UFE) and upper arm muscle area estimate (UME) to assess body composition. It has received considerable attention during the last decade (e.g. Bolzan et al. 1999; Chowdhury and Ghosh 2009; Sen et al. 2011; Senbanjo et al. 2014; Singh and Mondal 2014; Sen et al. 2015), but not been routinely adopted for assessment of body composition and nutritional status. Upper arm muscle area (UMA) and upper arm fat area (UFA) were introduced for assessment of nutritional status of children in different community settings. Several studies have subsequently been conducted among children using UMA and UFA as reliable measures of body composition and nutritional status (e.g., Erfan et al. 2003; Chowdhury and Ghosh 2009; Çiçek et al. 2009; Basu et al. 2010; Sen et al. 2011, 2015; Sikdar 2012; Singh and Mondal 2014).

The index of upper arm muscle area by height (UAMAH) is a relatively good upper arm based indicator to assess nutritional status of children (Frisancho and Tracer 1987). This anthropometric measure has received considerable importance during the last few decades, but has not been widely adopted for routine assessments of nutritional status. Although, it has been mainly utilized to assess physical growth and nutritional status related to body protein reserves, limited number of studies have used this index to assess nutritional status of individuals (e.g., Frisancho and Tracer 1987; Bolzan et al. 1999; Ozturk et al. 2009; Sen et al. 2011; Senbanjo et al. 2014). Another upper arm based index, which bears potential importance is MUAC-for-height, which can be used as a proxy indicator of nutritional status as it reflects low weight-for-height (Shakir 1973; Sommer and Loewenstein 1975) and is considered to be a very easy and reliable anthropometric measure to assess undernutrition(de Onis et al. 1997; Mei et al. 1997). However, very few studies have utilised this index to assess nutritional status among children (e.g., Anderson 1975; Mondal and Sen 2009). This index has been observed to be useful, especially when, in some field and clinical settings, age of the children remains difficult to determine (Mei et al. 1997).

Assessment of body composition and nutritional status are considered to be very challenging in India due to the country's large population size, poverty-stricken population groups, socio-economic disparities and backwardness, high percentage of illiteracy and inadequate access to health facilities (Mondal and Sen 2010; Sen et al. 2011; Sen and Mondal 2013). Moreover, body composition assessment represents a relative estimation of muscle mass and adiposity changes due to environment, early disease and nutritional status during childhood. Children are considered to be a very nutritionally susceptible group and only a handful studies, both in clinical and field settings have been carried out among those in the age group 5–12 years using upper arm anthropometry.Given the above, aims and objectives of the present study were to evaluate and describe age-specific body composition and nutritional status among rural school-going children aged 5–12 years using upper arm anthropometric measures (UMA, UFA, UAMAH and MUAC-for-height).

Material and methods

Study area and subjects

The present cross-sectional study was carried out among 1281 rural school-going children (boys: 619; girls: 662) aged 5–12 years. All of them were the residents of Phansidewa Block located under the district of Darjeeling, West Bengal, India. This block (Latitude 26°34'59'' N, Longitude 88°22'00' E) covers an area of 308.65 km^2. Based on the 2011 National Census, it has a total population of 171 508 individuals (males: 87,945; females: 83,563) and a literacy rate of 41.59% (males: 51.85%; females: 30.80%). The residents of this 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). The region is situated near the Indo-Bangladesh border and ~35– 40 km from the sub-divisional town of Siliguri.

The method of Lwanga and Lemeshow (1991) was used to estimate the minimum number of individuals required to be covered in course of the present study so as to have a reliable estimation of body composition and nutritional status. In this method, the anticipated population proportion of 50%, absolute precision of 5% and confidence interval of 99% are taken into consideration for estimating the minimum sample size. The minimum sample size, thus estimated was 664 children. The final sample size of 1281 children was higher than the minimum sample size required. The children selected were from a heterogeneous ethnic background viz., Bengalee Hindu caste, Bengalee Muslim, Rajbanshi and the conglomerate Proto-Australoid tribal groups (e.g., Santal and Munda). The community block consists of seven Gram Panchayets. A panchayet is a village level local government authority in India. Out of these seven Gram Panchayets, three of them were selected using random sampling method. There were twenty four primary schools situated under the three Gram Panchayets. For selecting the schools, following two criteria were considered:

(1) Student strength of at least 120 students so that the minimum sample size as estimated earlier could be covered.

(2) The schools had easy road accessibility.

Finally twelve primary schools were selected and data for the present study was recorded from students studying in those schools. The children were selected using the stratified random sampling method. The study was based on the representative sample of children across the schools under Phansidewa block. Initially 1387 children (boys: 694; girls: 693) in the age group of 5–12 years were identified so as to participate in the study. In the first stage, children belonging to the above-mentioned communities were identified based on their physical features, cultural backgrounds and surnames. In the second stage, their dates of birth were checked from the school records and subsequently verified from the birth certificates issued by the Government. Those children whose dates of birth were either not available in the school records or were not in the age group of 5–12 years wereexcluded. Of these 1387 children, 106 of them (boys: 75; girls: 31) were excluded from the study as their dates of birth were either not available or they were not in the age group selected. So the final sample consisted of 1281 children (boys: 619; girls: 662) aged 5–12 years. 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 socio-economic status (SES) of the children was evaluated using a modified version of the scale of Kuppuswamy (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 and has been used in many studies done in the field of nutritional research (e.g., Mondal and Sen 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014; Rengma et al. 2016). Data on SES was recorded from the parents through personal interviews conducted in the schools as well as through household visits. In order to elicit valid responses ample care was taken while briefing the questions to the respondents at the time of data collection. 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 in the Helsinki Declaration of 2000 (Touitou et al. 2004). The data were collected during the period from September 2015 to March 2016.

Anthropometric measurements recorded

Anthropometric measurements of height, weight, triceps skinfold (TSF) and MUAC were recorded using standard anthropometric procedures (Gibson, 2005; Hall et al. 2007). Height of the children was recorded to the nearest 0.1 cm with the help of an anthropometer rod and the head held on 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. TSF was measured using a Holtain skinfold caliper on the right side of each subject to the nearest to 0.2 mm, with the calliper 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. Special 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).

Intra-observer and inter-observer technical errors of the 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 coefficient 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 MUAC and TSF were recorded by two of the authors (SD and NM) from 50 children other than those selected for the study. Very high values of R (>0.975) were obtained for these measurements. As the values were observed to be within the acceptable limits of 0.95 as recommended by Ulijaszek and Kerr (1999), measurements recorded by SD and NM were considered to be reliable and reproducible. All measurements in course of the present study were subsequently recorded by one of the authors (SD).

Assessment of upper arm composition

Upper arm composition was assessed based on MUAC and TSF utilizing the standard equations of Frisancho (1981, 1989). The equations are appended below:

$$TUA\ cm^2 = (MUAC)^2 / (4\times\pi)$$

$$\text{UMA cm}^2 = \{\text{MUAC} - (\text{TSF}\times\pi)\}^2/(4\times\text{n})$$

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

$$\text{AFI} = \text{UFA}/\{(\text{MUAC})^2/(4\times\pi)\} \times 100$$

Assessment of body composition

Body composition was evaluated using the anthropometric indices of upper arm composition (UFE and UME) following Rolland-Cachera et al. (1997). The indices have been calculated using the following formulae:

a) UFE= MUAC × (TSF/2)

b) UME= $\{(\text{MUAC})^2/(4\times\pi)\}$–UFE

Assessment of nutritional status

Prevalence of undernutrition was evaluated in terms of UAMAH using the classification based on Z-scores for UAMAH as proposed by Frisancho and Tracer (1987). The classification is summarized below:

Category I (Wasted): < −1.60 Z-score.
Category II (Below average): −1.60 Z-score to <−1.00 Z-score.
Category III (Average): −1.00 Z-score to <+1.00 Z-score.
Category IV (Above Average): +1.00 Z-score to <+1.60 Z-score
Category V (High muscle): ≥ +1.60 Z-score.

The proposed age-sex specific classification of Mei et al. (1997) for MUAC-for-height was used to assess prevalence of wasting (low MUAC-for-height). The age and sex specific MUAC values were compared with the reference population for assessment of wasting. The children observed to be below −2SD and −3SD of the age-sex specific reference value were considered to be moderately and severely wasted respectively.

Statistical analysis

The data were analyzed using the Statistical Package for Social Science (version 17.0). Pearson correlation coefficient (r) analysis was done to document associations between the anthropometric variables. One way analysis of variance (ANOVA) was done to assess age and sex-specific mean differences in these variables. Two-way ANOVA was used to understand influences of age and sex on the anthropometric and upper arm composition variables. Chi-square (χ^2) analysis was done to assess sex-differences in nutritional status with respect to the different nutritional measures. The Yates correction term was taken into consideration in the case of chi-square analysis where the cells possessed less than five individuals. This correction term adds to the accuracy of χ^2 analysis when the numbers of classes are small. The *p*-values of <0.05 and <0.01 were considered to be statistically significant.

Results

Descriptive statistics of the anthropometric variables

The age-sex specific distribution of means and standard deviation (±SD) of the anthropometric and derived upper arm composition variables of height, weight, MUAC, TSF, TUA, UMA, UFA, AFI, UFE and UME of the children are depicted in Table 1. The age-sex specific mean height and weight were observed to be significantly higher among boys than girls ($p<0.05$). The age-sex specific mean height and weight increased with age, except in case of 12 years for height (in girls) and weight (in both sexes).

Table 1. Age- and sex-specific descriptive statistics (mean± standard deviation) of anthropometric variables among the children

Age (years)	N	Height/cm	Weight/kg	MUAC/cm	TSF/mm	TUA/cm^2	UMA/cm^2	UFA/cm^2	AFI	UFE/cm^2	UME/cm^2
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Boys											
5	54	107.91±6.66	16.47±2.79	15.36±1.51	8.11±2.31	18.94±3.81	13.19±2.71	5.75±1.97	30.17±6.53	6.31±2.33	12.63±2.73
6	72	111.77±6.00	17.71±2.54	15.60±1.13	7.64±1.81	19.46±2.86	13.95±2.31	5.51±1.45	28.32±5.50	6.00±1.71	13.47±2.37
7	96	115.68±6.66	19.14±2.84	15.90±1.33	7.42±1.70	20.26±3.39	14.78±2.77	5.48±1.39	27.08±5.25	5.93±1.60	14.32±2.80
8	91	122.04±6.79	20.90±2.98	16.48±1.65	7.17±2.02	21.82±5.11	16.28±4.15	5.54±1.82	25.29±5.80	5.98±2.06	15.85±4.14
9	113	126.97±5.58	22.98±3.10	16.79±1.40	7.52±2.90	22.59±3.97	16.67±2.67	5.92±2.57	25.76±7.32	6.43±3.09	16.16±2.78
10	88	130.26±6.18	26.12±5.43	17.83±2.17	8.83±4.03	25.66±6.83	18.15±3.05	7.52±4.48	27.77±7.76	8.25±5.30	17.41±2.68
11	69	134.15±6.74	27.74±5.48	18.11±1.90	7.88±3.00	26.37±5.92	19.63±3.85	6.74±3.27	25.10±7.00	7.30±3.80	19.07±3.75
12	36	135.24±7.45	27.06±4.43	17.66±1.66	7.69±1.89	25.02±4.75	18.65±3.56	6.37±1.93	25.36±4.97	6.86±2.17	18.15±3.51
Girls											
5	54	107.96±5.55	16.01±1.85	15.43±0.90	10.54±1.98	19.01±2.26	12.85±1.98	6.19±1.63	32.39±6.76	8.14±2.12	10.87±9.28
6	90	110.95±5.97	16.73±2.32	15.49±1.08	8.34±1.78	19.18±2.72	13.26±2.17	7.10±3.58	30.84±5.49	6.49±1.65	12.69±2.22
7	101	117.07±4.91	19.15±2.19	16.00±1.09	8.37±2.06	20.46±2.76	14.32±2.46	6.23±2.21	30.05±6.45	6.72±1.81	13.73±2.57
8	102	120.89±5.37	20.51±2.78	16.27±1.27	8.23±2.14	21.18±3.40	14.99±2.46	6.49±2.52	29.04±6.08	6.76±2.13	14.42±2.48
9	120	125.93±5.92	22.81±3.93	17.02±1.77	9.04±3.00	23.28±4.98	16.15±3.10	6.93±4.28	30.24±7.62	7.85±3.50	15.44±3.06
10	94	130.38±7.03	26.02±3.22	17.80±1.39	9.71±2.48	25.37±3.95	17.41±2.60	6.80±2.03	31.02±6.12	8.75±2.71	16.62±2.60
11	69	133.98±6.33	27.50±4.99	18.47±1.87	9.63±3.07	27.41±5.79	19.11±3.30	6.34±2.89	29.62±6.36	9.10±3.94	18.31±3.14
12	32	131.95±10.01	25.89±5.23	17.65±1.66	8.68±2.00	25.00±4.80	17.88±3.45	5.40±1.59	28.39±5.11	7.74±2.38	17.26±3.40
F-value		163.23	85.78	29.14	3.28	25.39	34.59	6.42	5.05	5.87	34.04
p-value		<0.0001	<0.0001	<0.0001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

MUAC – mid- upper arm circumference, TSF – triceps skinfold, TUA – total upper arm area, UMA – upper arm muscle area, UFA – upper arm fat area, AFI – arm fat index, UFE – upper arm fat area estimate, UME – upper arm muscle area estimate

The age and sex specific mean values of MUAC increased with age (5 years to 11 years), except in 12 years in both sexes. The age-specific mean MUAC ranged from 15.36 cm to 18.11cm (in boys) and 15.43 cm to 18.47 cm (in girls). The age-sex specific mean TSF values did not show any specific trend in both sexes, but the amount of adiposity was observed to be significantly greater among girls than boys ($p<0.05$).The mean age-specific TSF values ranged from 7.17 mm (in 8 years) to 8.83 mm (in 10 years) among boys and 10.54 mm (in 5 years) to 8.23 mm (in 8 years) years among girls. Results of the Pearson correlation co-efficient analysis showed that all the anthropometric variables were significantly correlated with upper arm composition measures (UMA, UFA, AFI and UFE) among both sexes ($p<0.01$), except AFI with height among girls and UME with TSF ($p>0.05$) among both boys and girls ($p>0.05$). Using ANOVA, the sex specific mean differences were observed to be statistically not significant ($p>0.05$) in height (F-value= 1.61, d.f., 1,1280), weight (F-value= 2.38, d.f., 1,1280), MUAC (F-value= 0.01, d.f., 1,1280), whereas, the differences were statistically significant in TSF (F-value= 38.44, d.f., 1,1280) between boys and girls ($p<0.01$). The age specific mean difference was observed to be statistically significant among both sexes using ANOVA ($p<0.01$) (Table 1). The results of two-way ANOVA showed statistically insignificant ($p>0.05$) differences with respect to age and sex in height (F-value= 1.36), weight (F-value=0.29), MUAC (F-value= 0.62) and TSF (F-value= 0.91).

Assessment of upper arm composition

Age and sex specific mean TUA and UMA values increased as the children approached higher ages (5 to 11 years), but an exception was observed in 12 years among both sexes. The age-specific mean TUA and UMA values were observed to be higher among boys than girls, except those aged 5 years, 7 years and 11 years (in TUA). Age and sex specific UFA values of boys decreased from 5 years to 7 years, although the amount of decrease was very low and subsequently increased from 7 years to 10 years and then again gradually decreased from 10 years to 12 years. The overall mean UFA was observed to be significantly higher among girls (6.56 ±2.95 cm) than boys (6.08 ±2.70 cm) ($p<0.05$). The age specific mean UFA was significantly higher among girls in early age groups (5 to 9 years), but was reverse in higher ages (10 to 12 years). The mean values of AFI did not show any age specific trend, but girls showed significantly higher age and sex specific mean values than boys ($p<0.05$). The mean age specific AFI values ranged from 30.17 (in 5 years) to 25.10 (in 11 years) and 32.39 (in 5 years) to 28.39 (in 12 years) among boys and girls, respectively. The age-specific mean UFE values did not exhibit any age-specific trend, but overall and age specific mean values were observed significantly higher among girls than boys, thereby indicating greater adiposity among girls ($p<0.05$). There was an increase in age and sex specific mean UME values as the children approached higher ages, except in case of 12 years. The overall and age-specific mean values were observed to be significantly greater among boys than girls, indicating greater muscularity in the former ($p<0.05$).

Using ANOVA, the sex specific mean differences were statistically significant ($p<0.05$) between boys and girls in UMA (F-value = 14.83, d.f., 1,1280), UFA (F-value = 27.83, d.f., 1,1280), AFI (F-value = 90.61, d.f., 1,1280), UFE (F-value = 25.94, d.f., 1,1280) and UME (F-value = 20.19, d.f., 1,1280) ($p<0.05$). The age-specific mean differences were also statistically significant ($p<0.05$) in the upper arm composition variables of TUA, UMA, UFA, AFI, UFE and UME among both boys and girls (Table 1). The results of two-way ANOVA showed statistically insignificant ($p>0.05$) differences with respect to age and sex in TUA (F-value = 0.69), UMA (F-value = 0.44), UFA (F-value = 1.16), AFI (F-value = 0.68), UFE (F-value = 0.97) and UME (F-value = 0.50).

Prevalence of wasting using upper arm muscle area by height (UAMAH)

Age and sex specific prevalence of undernutrition among the children was categorized according to the classification based on UAMAH as proposed by Frisancho and Tracer (1987) and the results are depicted in Table 2. A high proportion of the children were wasted (z-score< −1.60) (47.23%), below average (z-score −1.6 to −1.00) (24.82%) and average (z-score −1.00 to

Table 2. Prevalence of undernutrition (wasting) using UAMAH among the children

Age (years)	N	Difference grades of nutritional status			
		Wasted (<−1.60 z-score)	Below average (−1.60 to −1.00 z-score)	Average (−1.00 to 1.00 z-score)	Above average (1.00 to 1.60 z-score)
		Boys			
5	54	29 (53.70)	15 (27.78)	10 (18.52)	0
6	72	38 (52.78)	18 (25.00)	16 (22.22)	0
7	96	48 (50.00)	25 (26.04)	22 (22.92)	1 (1.04)
8	91	49 (53.85)	25 (27.47)	16 (17.58)	1 (1.10)
9	113	71 (62.83)*	23 (20.35)	18 (15.93)	1 (0.89)
10	88	43 (48.86)	23 (26.14)	22 (25.00)	0
11	69	29 (42.03)	15 (21.74)	24 (34.78)	1 (1.45)
12	36	22 (61.11)	8 (22.22)	6 (16.67)	0
Total	619	329 (53.15)*	152 (24.56)	134 (21.65)**	4 (0.65)
		Girls			
5	54	28 (51.85)	17 (31.48)	9 (16.67)	0
6	90	42 (46.67)	27 (30.00)	21 (23.33)	0
7	101	49 (48.51)	28 (27.72)	22 (21.78)	2 (1.98)
8	102	50 (49.01)	24 (23.53)	28 (27.45)	0
9	120	46 (38.33)*	29 (24.17)	45 (37.50)	0
10	94	36 (38.30)	16 (17.02)	41 (43.62)	1 (1.06)
11	69	16 (23.19)	16 (23.19)	35 (50.72)	2 (2.90)
12	32	9 (28.13)	9 (28.13)	14 (43.75)	0
Total	662	276 (41.69)*	166 (25.08)	215 (32.48)**	5 (0.76)

UAMAH – Upper arm muscle area by height. Values in parentheses indicate percentage. Statistically significant at *$p<0.05$, at **$p<0.01$.

+1.00) (27.24%). Prevalence of wasting was observed to be higher among boys (53.20%) than girls (41.70%), indicating that boys were more affected by wasting ($p<0.05$). The overall prevalence of below average (25.08% vs. 24.56%) and average (z-score −1.00 to +1.00) (32.48% vs. 21.65%) was observed to be higher among girls than boys. The sex difference was observed to be statistically significant in overall wasting ($\chi 2$-value= 6.03; $p<0.05$), average wasting (χ^2-value= 10.87; $p<0.05$) and age-specific prevalence of wasting among 9 years (χ^2-value= 4.34; $p<0.05$) between sexes using χ^2 analysis ($p<0.05$).

Prevalence of wasting (low MUAC-for-height)

Age and sex specific prevalence of wasting among the children using the reference value of MUAC-for-height by Mei et al. (1997) is depicted in Table 3. The prevalence of overall (28.59% vs. 25.68%), moderate (25.25% vs. 22.51%) and severe (3.39% vs. 3.17%) grades of low MUAC-for-height was observed to be higher among boys than girls. Age specific prevalence of overall low MUAC-for-height was observed to be higher among boys and girls aged 7 years (37.50%) and 8 years (34.31%), whereas lower preva-

Table 3. Prevalence of undernutrition (wasting) using MUAC-for-Height among the children

Age (years)	N	Prevalence of wasting (low MUAC-for-Height)		
		Overall (<−2 SD)	Moderate (<−2 SD to −3SD)	Severe (<−3 SD)
Boys				
5	54	20 (37.04)	13 (24.07)	7 (12.96)*
6	72	25 (34.72)	23 (31.94)	2 (2.78)
7	96	36 (37.50)	28 (29.17)	8 (8.33)
8	91	28 (30.77)	26 (28.57)	2 (2.20)
9	113	30 (26.55)	28 (24.78)	2 (1.77)
10	88	17 (19.32)	17 (19.32)	0
11	69	13 (18.84)	13* (18.84)	0
12	36	8 (22.22)	8 (22.22)	0
Total	619	177 (28.59)	156 (25.20)	21 (3.39)
Girls				
5	54	13 (24.07)	13 (24.07)	0*
6	90	29 (32.22)	26 (28.89)	3 (3.33)
7	101	31 (30.69)	26 (25.74)	5 (4.95)
8	102	35 (34.31)	32 (31.37)	3 (2.94)
9	120	25 (20.83)	20 (16.67)	5 (4.17)
10	94	19 (20.21)	17 (18.09)	2 (2.13)
11	69	10 (14.49)	8 (11.59)	2 (2.90)
12	32	8 (25.00)	7 (21.88)	1 (3.13)
Total	662	170 (25.68)	149 (22.51)	21 (3.17)

Values in parentheses indicate percentage. Statistically significant at *$p<0.05$, at **$p<0.01$.

lence was observed among those aged 11 years (18.84% and 14.49% respectively). The age-sex specific prevalence of moderate low MUAC-for-height ranged from 18.84% (11 years) to 31.94% (6 years) and 11.59% (11 years) to 31.37% (8 years) among boys and girls, respectively. The age specific prevalence of severe wasting was observed to be higher in 5 years (12.96%) among boys and 7 years (4.95%) among girls. Using χ^2 analysis, the sex differences were observed to be statistically not significant ($p>0.05$) in overall, moderate and severe low MUAC-for-height, except for severe low MUAC-for-height in 5 years (χ^2-value: 4.744; $p<0.05$).

Discussion

Regional adiposity is arguably of greatest importance in both evolutionary and biomedical contexts, as researchers have increasingly appreciated the metabolic and functional differences between discrete adipose depots. Integral to such developmental changes in adipose adiposity and distribution is a life-course pattern of sexual dimorphism, strongly indicative of differing selective pressures acting on both the sexes (Wells 2010). Population variations in body composition in terms of amount of muscularity and adiposity, and nutritional status can be attributed to several associated factors such as sex and ethnicity, dietary intake, food habits, physical exercise patterns, socio-economic status and burden of infectious disease in the same (He et al. 2004; Wells 2007; Sen et al. 2011; Thibault and Pichard 2012; Thibault et al. 2012; Sen and Mondal 2013; Singh and Mondal 2014; Senbanjo et al. 2014). In the present study, the study population was a largely heterogeneous ethnic group of Bengalee caste, Bengalee Muslim, Rajbanshi and Proto-Australoid tribal population. Moreover, the extent to which population variability in body composition derives from genetic factors is unknown and adiposity has a degree of heritability, and ethnic genetic variability in both physique and body adiposity distribution is certainly plausible (Wells 2010). Multi-generational exposure to particular environmental conditions may generate 'heritability' of body composition without operating through genetic mechanisms. Whatever the genetic contribution to population variability in body composition, it is clear that there are important differences between global regions. As such, the children selected for the study were the residents of the same region and belonged to the lower to middle SES, as determined by the modified scale by Kuppuswamy's (Mishra and Singh 2003; Kumar et al. 2007). Therefore, the environmental conditions and poor socio-economic status remained similar in the present study as all the children were from the same ecological habitat. Such variations in body composition can have a constant pattern caused due genetic and ancestral environment and also exposed to more contemporary ecological stress (Wells 2010).

Research studies have advocated that anthropometric measures are very useful and play a pivotal role to monitor body composition, nutritional status and for evaluating the effects of target specific intervention and supplementary programmes (Rolland-Cachera 1993; Gibson 2005; Hall et al. 2007). Anthropometric assessment of body composition and nutritional status has received a considerable attention in epidemiological and clinical investigations among populations due to its reliability, low cost, simplicity and non-invasiveness. Skinfold thicknesses (e.g., TSF, biceps or sub-scapular) remain very useful in quantifying the amount of adiposity and muscularity among children and adolescents (Gültekin et al. 2006; Basu et al. 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014; Senbanjo et al. 2014). These measurements are widely accepted as body fatness predictors because subcutaneous fat (i.e., 40–60% of total body fat) can be directly measured with a skin-fold calliper that has been shown to have a strong correlation with body adiposity (Heimmel et al. 2007; Nooyens et al. 2007). Several studies have been done among different populations for establishing population specific reference values related to upper arm composition (e.g., Bolzan et al. 1999; Gültekin et al. 2006; Monir et al. 2008; Çiçek et al. 2009, 2014; Basu et al. 2010; Sikdar 2012; Senbanjo et al. 2014; Singh and Mondal 2014). In the present study, it was observed that muscularity related to UMA and UME was higher among boys than girls ($p<0.05$). Sex related effects might be controlling muscularity of boys and girls and it is the reason behind greater muscularity of boys. Similar trends were reported among Indian (Chowdhury and Ghosh 2009; Basu et al. 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014), Argentinean (Bolzan et al.1999), South Korean (Kim et al. 1999), Kenyan (Semproli and Gualdi-Russo 2007), Zimbabwean (Olivieri et al. 2008), Turkish (Ozturk et al. 2009) and Nigerian (Senbanjo et al. 2014) children. The comparison of age- and sex-specific mean values of muscularity of children of the present study with their American counterparts (Frisancho 1981) reflects a very poor nutritional status. The age-specific mean values of the children were also observed to be distinctly lower than those reported from Zimbabwean (Olivieri et al. 2008), Argentinean (Bolzan et al. 1999), Kenyan (Semproli and Gualdi-Russo 2007) and Turkish (Çiçek et al. 2014) children. The age- and sex-specific mean values of UMA among boys and girls in the present study were also observed to be distinctly below the mean values reported from similar studies among Santal (Chowdhury and Ghosh 2009), Bengali Muslim (Sen et al. 2011), Mishing (Sikdar 2012) and Sonowal Kachari (Singh and Mondal 2014).

Assessment of body composition may be integrated into routine field and clinical investigations for initial assessment and sequential follow-up of nutritional status of the children belonging to the nutritionally vulnerable segments of the population. Moreover, these measurements of specific aspects of body composition offer the potential to achieve marked improvement in both characterizations of diseases and the assessment of alternative management strategies (Wells 2003). The amount of body adiposity differs with age, sex, environmental conditions and genotype and serves as a good indicator of the health and nutritional status of children (Rolland-Cachera 1993; He et al. 2004; Wells 2007, 2010; Sen and Mondal 2013). The results showed that the age- and sex-specific mean of adiposity measures of TSF, UFA, AFI and UFE were observed to be significantly higher among girls than boys, thereby indicating distinct sexual dimorphism in subcutaneous body fat patterning among the children ($p<0.01$) (Table 1). Sexual dimorphism in body composition and fat patterns primarily attributed to the action of sex steroid hormones (He et al. 2004; Wells 2007, 2010; Sen and Mondal 2013). Estrogen increases fat storage, resulting in more fat storage in females than in males. In contrary, testosterone reduces subcutaneous fat in males by aiding fat metabolism. This accumulation of body fat before puberty (i.e., pre-puberty) is important in determining the time of onset of puberty. Studies have shown that gonadotropins and sex steroids gradually increase in pre-pubertal children, implying that their effects may be more pronounced in older than younger pre-pubertal children (Mitamura et al. 1999, 2000; He et al. 2004; Wells et al. 2007). Such differences may be observed due to tempo of adipose tissue accumulation being likely to be greater in girls than boys, and to the schedule of pubertal maturation (Wells 2007, 2010). It may be mentioned here that the onset of puberty appears to be regulated by a number of complementary mechanisms, including genotype, intrauterine conditions, sex-specific mechanism and nutritional status (He et al. 2002; Parent et al. 2003; Wells 2007). Moreover, there are evidences that sex differences in body composition existed prior to puberty and the same trend was observed in the present study (in UFA, AFI and UFE), where sex specific differences were reported in the adiposity measures (i.e., UFA and AFI) and body fat percentages (He et al. 2002; Basu et al. 2010; Sen et al. 2011; Singh and Mondal 2014). The results of the present study (e,g., UFA) are reported in accordance with the findings from children from the United States (Frisancho 1981), Turkey (Gültekin et al. 2006), Zimbabwe (Olivieri et al. 2008) and Nigeria (Senbanjo et al. 2014) and India (Sen et al. 2011; Singh and Mondal 2014) but contrary to the reported trends for Santal tribal children of West Bengal (Chowdhury and Ghosh 2009). The comparison with reference data also shows that the children tend to have lower age-specific mean values of UFA as compared to 5th percentile reference children from the United States (Frisancho 1981), Argentina (Bolzan et al. 1999) and Turkish (Çiçek et al. 2014). However, age-and sex-specific mean values of UFA of the children of present study were observed to be similar among children from Zimbabwe (Olivieri et al. 2008). The values are also similar to those reported for Santal (Chowdhury and Ghosh, 2009), Bengali Muslim (Sen et al. 2011), Mising (Sikdar 2012) and Sonowal Kachari (Singh and Mondal 2014). Therefore, it seems that the comparative evaluation of upper arm compositions (e.g., UMA and UFA) have prime importance to assess the existing body composition, vulnerability of nutritional status and provides the indication of required the follow up nutritional support.

The UAMAH and MUAC-for-height are considered to be two interesting indices for use in the developing countries when age is either not available or not appropriate. In such cases, these proposed conventional upper arm based anthropometric measures be used to identify the relative risks in populations with chronic undernutrition where both muscle mass and fat mass remain depleted (Mei et al. 1997; Bolzan et al. 1999). Very recently, researchers have started to advocate that use of UAMAH has improved the screening of chronic undernutrition in studies, and hence seems to be a more appropriate indicator of undernutrition among children (Sen et al. 2011; Singh and Mondal 2014; Senbanjo et al. 2014). Several studies have reported strong correlations between upper arm anthropometric measures with height and conventional measures of undernutrition among children (e.g., Frisancho and Tracer 1987; Bolzan et al. 1999; Sen et al. 2011). Results of the present study showed a high prevalence of undernutrition using both UAMAH and MUAC-by-height among the children (Tables 2 and 3). The age-sex specific UAMAH, MUAC-for--height, UMA and UFA were observed to be more affected with respect to nutritional status and seemed to have greater roles to play, as majority of the children were observed to be below the 5th percentile of the reference (Frisancho 1989). Additionally, the results show high prevalence of undernutrition (wasting) among both boys (53.15%) and girls (41.69%) using UAMAH (p<0.05). This could be indications of lower muscularity and lower fat accumulation due to adipose tissue depletion occurring before utilization of protein reserves begin in the child's manifestation of chronic undernutrition (Frisancho and Tracer 1987; Wang et al. 2006; Senbanjo et al. 2014). A comparison showed that prevalence of wasting was observed to be 43.1–45.3% among Santal (Chowdhury and Ghosh 2009), 88.50–91.28% among Bengalee Muslim (Sen et al. 2011), 14.84–17.32% among Sonowal Kachari (Singh and Mondal 2014) and 10.22–23.38% among Nigerian (Senbanjo et al. 2014) children. It is generally believed that the greater amount of muscularity would reflect a greater protein reserve in children (Frisancho 1974, 1989; Frisancho and Tracer 1987). Therefore, high prevalence of wasting among children in the present study indicates poor physical growth attainment in terms of lower protein reserves and indicative of chronic undernutrition. The principal cause of undernutrition among these children may be attributed to, illiteracy, disease prevalence and lack of access to sufficient food and resource amenities (Mondal and Sen 2010; Sen and Mondal 2013; Rengma et al. 2016). The continuation of poor muscle and adiposity pattern is probably due to their poor nutritional status as reflected in the conventional upper arm indices. Use of upper arm anthropometric measures (such as UAMAH and MUAC-for-height) has improved the accuracy of undernutrition assessment and hence seems to be an indicator of undernutrition. This could allow for an objective and body composition management, systematic and early screening of ill-health condition and promote rational and early initiation of optimal nutritional and health care support, thereby reducing the prevalence of morbidity, mortality and thereby worsening of the quality of life and global healthcare costs in population (Thibault et al. 2012; Thibault and Pichard 2012).

Conclusion

Upper arm anthropometry seems to be an important technique to determine body composition and nutritional status, especially in epidemiological, clinical diagnosis and disease prevalence. Findings of the present study are important in providing more insight for future studies in the field and large epidemiological settings so as to accurately identify the risk of lower or higher adiposity status and propose a major opportunity to improve through proper intervention programmes. Further studies are needed to confirm the clinical associations and manifestation with body composition and nutritional status. The present study is a cross-sectional one and did not focus on associations of nutritional status with socio-economic and demographic indicators and has its own limitations. Another limitation of the present study was that it did not consider the issue of attainment of menarche among girls although there is a significant relationship between onset of menarche and fat body accumulation among girls (Lassek and Gaulin 2007; Wells 2010). Moreover, some comparison of different methods can be done to assess the superiority of upper arm indicators to any other method of study. The present study recommends the use of upper arm anthropometry, UAMAH and MUAC-for-height to assess body composition and undernutrition (e.g., wasting) of children so as to improve screening of undernutrition in epidemiological and clinical investigations and to accurately identify the risk of lower or greater adiposity and muscularity.

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Author contribution

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

The authors declare that there is no conflict of interests.

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