Anthropological Review • Vol. 83(1), 1–17 (2020)

sciendo

ANTHROPOLOGICAL REVIEW
Available online at: https://doi.org/10.2478/anre-2020-0003

Age and sex specific variations in body composition in Indian urban Bengali Hindu children, adolescents and young adults aged 7–21 years

Saijuddin Shaikh[1], Rituparna Das[2], Rana Saha[3], Sukanta Das[4], Parasmani Dasgupta[2]

[1]Department of International Health, Johns Hopkins University, MD, USA
[2]Biological Anthropology Unit, Indian Statistical Institute, Kolkata, India
[3]Department of Anthropology, Dinabandhu Mahavidyalaya, West Bengal, India
[4]Department of Anthropology, North Bengal University, West Bengal, India

ABSTRACT: Childhood and adolescent obesity is a public health concern worldwide. However, little attention has been paid on status of overweight and body composition of Indian Bengali urban middle and high SES population. The objective was to determine the prevalence of overweight and body composition status by age and sex in children, adolescents and young adults. This cross-sectional study was carried out among 4194 unmarried school and college students (1999 males and 2195 females) aged 7–21 years belonging to the Bengali Hindu Population in Kolkata, India. The survey period was from 1999 to 2011. Anthropometry of participants were measured. Age and sex specific ≥85 percentile of body mass index (BMI) for children (<18 years of age) and BMI ≥23 kg/m^2 (≥18 years of age) for adults were used to define overweight. Fat percent, upper arm fat area (UAFA) and upper arm muscle area (UAMA) were estimated. Simple linear regression was performed to check trend of changes with age. The overall prevalence of overweight was 14.8% in both sexes. Mean fat percent was higher in females than males (23.5% vs 13.5% respectively; $p<0.001$) and it increased by 0.18% (0.02) in males and 0.56% (0.02) in females per year (both $p<0.001$). UAMA gradually increased with age in both sexes and increasing rate per year was by 2.07 (0.04) cm^2 in males and 1.19 (0.04) cm^2 in females (both $p<0.001$). However, UAFA increased by 0.41 (0.03) cm^2 and 0.90 (0.03) cm^2 every year in males and females respectively (both $p<0.001$). Sum of biceps, triceps, subscapular and suprailliac skinfolds increased by 1.66 (0.06) mm and 0.5 (0.07) mm per year in females and males respectively (both $p<0.001$). Overall prevalence of overweight was the same in both sexes but adipose tissue was higher and muscularly was lower in females than males.

KEY WORDS: overweight, fat percent, upper arm muscle area, upper arm fat area, West Bengal

Original Research Article Received: October 6, 2019; Revised: January 24, 2020; Accepted: February 1, 2020
DOI: 10.2478/anre-2020-0003

Introduction

Childhood and adolescent obesity is a big health concern worldwide (WHO 2000; Ford and Mokdad 2008). Recent studies from western populations have demonstrated that the prevalence of childhood and adult obesity increased during the last decade (Flegal et al. 2010; Lissner et al. 2010; Ogden et al. 2010) and overweight in the US and UK has increased significantly to about 16–20% (Hedley et al. 2004; Lobstein et al. 2003). In recent time, developing countries have also reported an increasing incidence of obesity (Kelishadi 2007).

Although, childhood under-nutrition has been a major public health concern in India over the last several decades, little attention has been paid to childhood and adolescents overweight and obesity until recently (Subramanyam et al. 2010). The current evidence suggested an increase in over-nutrition status among children as well as adults (Bhardwaj et al. 2008; Singhal et al. 2010). Numerous studies have reported prevalence of obesity in children and adolescents to be 12–29% from different part of India (Kapil et al. 2002; Chhatwal et al. 2004; Bhardwaj et al. 2008). The National Family Health Survey (NFHS-3) data showed that the prevalence of obesity (BMI≥25 kg/m^2) was 9.3% in men and 12.6% in women aged 15–49 years (NFHS 2005). A group of researchers have reported prevalence of overweight in the range of 22–25% in children and young adolescents in Delhi (Bhardwaj et al. 2008; Sharma et al. 2007; Kapil et al. 2002). Other studies found the prevalence of overweight is escalating among school going children and adolescents in different urban areas of India (Kotain 2010; Mahato et al. 2015).

Increasing prevalence of overweight in India may be attributed to different factors, such as sedentary life-style, unhealthy food habits, cultural practices, increasing affluence of middle class population and urbanization (Goel et al. 2010; Misra et al. 2007; Misra and Vikram 2004). It is reported that obesity associated with multiple co-morbidities like type 2 diabetes mellitus, dyslipidemia, polycystic ovarian disease, hypertension and metabolic syndrome which are increasingly becoming common among children and urban adolescents (Ford and Mokdad 2008; Bhardwaj et al. 2008; Misra et al. 2007). Further, it is important to mention that childhood obesity is associated with higher risk of morbidity and mortality in adult life (Must et al. 1992).

On the other hand, other physiological parameters like mid upper arm fat and muscle areas, and body fat percent are indicators of over-and under-nutrition in human body. Cross-sectional UAMA and UAFA are used for assessment of nutritional status in community setting. UAFA is shown to be an indicator of adiposity in the form of fat and is considered to an indicator of body fat (Frisancho 1981). Also skinfold thicknesses proxy indicator of overweight where BMI underestimate overweight in South Asian population (Shaikh et al. 2016; Dudeja et al. 2001). Studies showed that fat deposition is increasing recently particularly in urban area due to urbanization, junk foods consumption and less physical activities (Rosenheck 2008; Christensen et al. 2008). It is also evidenced that fat deposition is different between sexes due to hormonal changes (Roemmich and Rogol 1999).

However, little attention has been paid on status of overweight, body fat

mass and muscle mass of Bengali urban middle and high SES Hindu population from Kolkata which is culturally different from other parts of India. The objective of this study was to determine the prevalence and changes of overweight and body composition by age and sex in children, adolescents and young adults in urban area of West Bengal, India.

Subjects and Methods

The present cross-sectional growth survey of 1999 to 2011 was carried out on Bengali Hindu urban middle class school and college students in Kolkata city, West Bengal, India. Though the present survey period was from 1999 to 2011, but the data for males were collected from 1999 to 2011 and data for females were collected from 2005 to 2011. Socioeconomically middle class was defined on the basis of the following criteria: per capita monthly family expenditure, parental occupation, education, school affiliation, household assets, housing condition, dietary habits, recreational and cultural activities, physical activities etc. (Brandy and Büge 2014; Chun 2010; Banerjee and Duflo 2008). In the present study, purposive sampling method was applied to select the sixty six academic institutions in Kolkata city and the inclusion of a specific institution depends on the judgment or decision of the researcher (Tongco 2007). The inclusion criteria of subjects' selection were: subjects should be aged from 7 to 21 years and have authentic document for his/her date of birth, they should be free from any physical disability and not dependent on any medication during the time of survey, they should be unmarried and representative of middle class families, brought up in the household environment under parental care and living in the city for a fairly long period of time etc. A total 4,194 subjects (1,999 males and 2,195 females) aged from 7 to 21 years had participated in this study. All subjects were participated voluntarily in this survey in response to the appeal made by the administrations of the respective academic institutions. Data were collected at their respective households only during day time usually between 7 am and 2 pm. A written consent was obtained from the parents for both minor and adult participants. Study design and subjects selection were described previously (Das et al. 2016). This study was approved by the Ethical Committee for research risks to human subjects, Indian Statistical Institute prior to data collection.

Data collection

The following socioeconomic, demographic and household data were collected using a structured questionnaire: fathers' and mothers' education, fathers' and mothers' occupation, caste, sibling size, family type, number of family members, number of toilets, number of rooms, type of possession of the household, source of drinking water and monthly family expenditure. Completed age was recorded on the day of measurement. Anthropometric measurements were collected by extensively trained anthropometrists. Each anthropometrist was trained and standardized at the beginning of the study. The intra- and inter- worker technical errors of measurement (TEM) were calculated (Perini et al. 2005) and compared with cutoff points at 1.0% and 1.5% for intra- and inter- TEMs respectively. If the calculated TEMs of any worker exceeded the cutoff points then the worker was

standardized again before measurement. To ensure accuracy of measurements, the equipments were checked and calibrated every day before the measuring session. Accordingly, measurement sessions have been continued throughout the year. Subject's weight with light clothing and barefooted was taken using Libra portable analogue weighing machine with precision of ±500 g. Standing height was measured to the nearest 0.1 cm using GPM portable anthropometer. Mid-upper arm, head and calf circumferences were measured to the nearest 0.1 cm by a non-stretch steel tape. The skinfold thicknesses were taken within 0.5 mm precision with a pressure of 10 g per mm square using Lange Skinfold caliper. All measurements except weight were taken triplicate and median values were used in the analysis. Standard procedures were performed following the protocol of International Biological Programme (Weiner and Lourie 1969). Details of the methods and field activities were presented in earlier publication (Das et al. 2016).

Upper arm muscle and fat areas were estimated based on mid-upper arm circumference and triceps skinfold thickness using the established equations (Frisancho 1981) which were used in Bengali population previously (Sen et al. 2011; Debnath et al. 2017).

$$\text{UAMA } (\text{cm}^2) = \{\text{MUAC} - (\text{TSF} \times \pi)\}2/ /(4 \times \pi) \quad (1)$$

$$\text{UAFA } (\text{cm}^2) = \{(\text{MUAC})^2/(4 \times \pi)\} - - \text{UAMA} \quad (2)$$

where: MUAC – mid-upper arm circumference in cm, TSF – triceps skinfold thickness in cm, UAMA – upper arm muscle area, UAFA – upper arm fat area.

Fat mass percent was estimated from skinfold thicknesses. First, density was calculated using the logarithm of total skinfold thicknesses (biceps + triceps + subscapular + supraliliac) (Durnin and Womersley 1974) and then fat percent was assessed from density using Siri's equation (1956). This Siri's equation was used by Shaikh et al (2016) in Bangladeshi female population earlier.

$$\text{Percent body fat} = \{(4.95/\text{density}) - - 4.50\} \times 100 \quad (3)$$

Age and sex specific BMI (kg/m^2) was calculated for children and adolescents and ≥85 percentile was used to identify overweight (Cole et al. 2000). For adults, ≥18 years of age, Asian cutoff point ≥23 of BMI (kg/m^2) was applied to find overweight (WHO 2004).

Statistical analysis

Data were presented as n (%) for categorical variables and mean±SD for continuous variables. Age was grouped as 7–11 years (school age), 12–17 years (adolescents) and 18–21 years (adults). Parent's educational level were categorized into categories of completed class 1 to 10, completed class 11 to 14, and graduated and higher. Parent's occupation were categorized as business, service and retired. Family caste was divided as general, other backward class and scheduled caste. Sibling was grouped as one, two and three or more, and family type as joint and simple families. Family member was specified as three or less, four to five and six or more. Mean upper arm muscle and fat areas and total skinfold thickness were estimated and presented by age as line graph with 95% confidence interval to see changes of

each parameter between sexes. Correlation coefficients (r) were calculated between BMI and fat percent estimated by skinfold thickness. Log value of derived variables was calculated and used in simple linear regression to find the trend of change with age and β-value with SE were presented. The Chi^2 test was performed to test the significant differences among categorical variables. Pairwise t-test was done to determine the age specific mean difference between males and females and $p<0.05$ was considered significant for all tests. Statistical analyses were performed using STATA 11 software (STATA Corp, College Station, Texas).

Results

The sample size by age and sex in these two studies are depicted in Table 1.

Household and demographic characteristics were different between males and females (Table 2).

Fathers and mothers of female participants were higher educated than fathers and mothers of male participants (father: 64% vs 61%; $p<0.01$ and mother: 43% vs 35%; $p<0.001$, respectively). About 57% fathers of female participants and 52% fathers of male participants were service men. Comparatively, less mothers of female participants were housewives (female, 87% vs male, 92%; $p<0.001$) and more sibling were found in male group than female group ($p<0.01$). It has also been noticed that family members were higher in male group than female group ($p<0.001$) Owned house between two groups were different ($p<0.001$) and there were more drinking water taps in male households compared to female households ($p<0.001$). Comparatively monthly expenditure was higher in female than male group (Table 2). Monthly expenditure 10001–15000 rupees and above 15000 rupees were higher in females than males (26.8% vs 18.3%; $p<0.001$ and 14.3 vs 5.6%; $p<0.001$ respectively).

Table 1. Number of samples by age and sex in two survey periods

Age (years)	Male (n=1999)[1]	Female (n=2195)[2]	Total (n=4194)
7	123	155	278
8	125	156	281
9	130	151	281
10	117	161	278
11	124	143	267
12	149	145	294
13	159	140	299
14	137	141	278
15	127	148	275
16	138	135	273
17	143	139	282
18	128	136	264
19	132	146	278
20	135	158	293
21	132	141	273

[1]Survey years: 1999–2011.
[2]Survery years: 2005–2011.

Age was grouped as school aged, adolescents and adults and age specific mean values of physical parameters of study participants were compared between males and females (Table 3).

Pairwise t-test conformed that there was no difference of weight and BMI between males and females in school aged children and UAMA was higher in females than males in school aged children ($p<0.001$), but it altered with age and higher in males than females among adolescents and adults ($p<0.001$). There was significant difference of other parameters between males and females and between the same age group (Table 3).

Table 2. Household and demographic characteristics of study participants

Variable	Male (n=1999)[1]		Female (n=2195)[2]		*p*-value[3]
	n	%	n	%	
Father's education					
01–10 year of schooling	474	23.8	516	23.6	<0.01
11–14 year of schooling	303	15.2	265	12.1	
Graduate and above	1213	61.0	1408	64.3	
Mother's education					
01–10 year of schooling	830	41.8	849	38.7	<0.001
11–14 year of schooling	465	23.4	397	18.1	
Graduate and above	69	34.8	946	43.2	
Father's occupation					
Business	911	45.6	874	39.8	<0.001
Service	1040	52.1	1246	56.8	
Retired	47	2.3	72	3.4	
Mother's occupation					
Business	48	2.4	92	4.2	<0.001
Service	111	5.6	193	8.8	
Housewife	1840	92.0	1899	87.0	
Caste affiliation					
General	1632	81.6	1954	89.0	<0.001
Other backward class	255	12.8	35	1.6	
Scheduled caste	112	5.6	206	9.4	
Sibling					
One	933	46.7	1116	50.8	<0.01
Two	964	48.3	996	45.4	
Three or more	101	5.0	83	3.8	
Family type					
Nuclear family	777	38.9	795	36.2	0.118
Single-parent family	1221	61.1	1400	63.8	
Family member					
Three or less	580	29.0	709	32.3	<0.001
Four to five	977	48.9	1123	51.2	
Six or more	441	22.1	363	16.5	
Toilet number					
One	1358	68.6	1279	58.3	<0.001
Two	527	26.6	732	33.4	
Three or more	95	4.8	183	8.3	
Rooms Number					
1–3	839	43.2	863	39.7	<0.05
4–6	918	47.3	1120	51.5	
7 or more	185	9.5	192	8.8	
Type of house possession					
Owned house	1445	72.8	1881	85.8	<0.001
Rented house	540	27.2	311	14.2	

Variable	Male (n=1999)[1]		Female (n=2195)[2]		*p*-value[3]
	n	%	n	%	
Source of drinking water					
Community tap	115	5.8	398	18.1	<0.001
Own tap	1842	92.8	1695	77.3	
Others	29	1.4	100	4.6	
Monthly expenditure, rupee					
Up to 5000	355	17.8	259	11.8	
5001–10000	1166	58.3	1033	47.1	
10001–15000	366	18.3	588	26.8	
Above 15000	112	5.6	315	14.3	<0.001

Missing data: Father's education, 9 for male and 6 for female; Mother's education, 13 for male and 3 for female; Father's occupation, 1 for male and 3 for female; Mother's occupation, 11 for female; Sibling, 1 for male; Family member, 2 for male; Toilet number, 19 for male and 1 for female; Room number, 57 for male and 20 for female; Type of possession, 14 for male and 3 for female; Source of drinking water, 13 for male and 2 for female.
[1]Survey years: 1999–2011.
[2]Survery years: 2005–2011.
[3]Chi-square and Fisher exact tests have been done to find significant level.

The overall prevalence of overweight was 14.8% which was similar in both sexes. Some selected SES characteristics were related with overweight in both males and females are shown in Table 4.

Chi-square test confirmed that overweight significantly associated with father's education, father's occupation, family caste, and room number only in females but not in males (Table 4) ($p<0.01$). However, sibling and family members associated ($p<0.05$) with overweight in males only. Although, number of toilet and family monthly expenditure associated with overweight both in males and females ($p<0.05$).

The overall correlation between BMI and fat percent was 0.84 and 0.75 in females and males respectively (all $p<0.001$) which was higher in females than males. However, age stratified analysis showed that in females, the correlation coefficient was 0.85 in under 17 years of age and 0.73 in 17 years and above. Whereas, opposite direction was noticed in males, the correlation coefficient was 0.73 in below 17 years of age but it was 0.83 for 17 years and above.

Upper arm muscle area (UAMA) is plotted against age to show the changing pattern both in males and females (Fig. 1).

It gradually increased with age in males, however, plateaued after 14 years of age in females. Simple linear regression analysis confirmed that the trend of changes with age was significant ($p<0.001$) and by 2.07 (0.04) and 1.19 (0.04) cm^2 UAMA increased each year in males and females respectively. Figure 2 shows the changing pattern of upper arm fat area. It increased with age in both sexes but increasing rate was higher in females than males. Upper arm fat area increased by 0.41 (0.03) cm^2 in males and 0.90 (0.03) cm^2 in females every year (both $p<0.001$).

Biceps, triceps, subscapular and suprailiac skinfold thicknesses were sum-

Table 3. Age group and sex wise physical parameters of study participants

Variable	Males (n=1999)[1]			Females (n=2195)[2]		
	Age 7–11, y (n=619)	Age 12–17, y (n=853)	Age 18–21, y (n=527)	Age 7–11, y (n=766)	Age 12–17, y (n=848)	Age 18–21, y (n=581)
Height, cm	131.6±9.5	160.1±10.2	169.5±6.0	130.5±10.5*	152.5±6.3***	154.5±5.7***
Weight, kg	29.6±0.5	49.8±12.3	60.1±11.5	29.3±8.6	47.5±10.6***	53.5±10.4***
Mid upper arm circumference, cm	19.6±3.3	23.8±3.8	26.4±3.4	20.4±3.3***	24.4±3.6**	26.1±3.3
Head circumference, cm	51.3±1.6	53.4±1.7	54.3±1.5	50.3±1.6***	52.3±1.5***	52.6±1.4***
Calf circumference, cm	26.6±3.3	32.2±3.7	34.0±3.5	26.8±3.3	32.2±3.6	34.1±3.4
Biceps skinfold, mm	5.6±2.2	5.5±2.4	5.5±2.7	7.8±3.0***	9.2±3.8***	10.3±3.5***
Triceps skinfold, mm	10.8±3.8	11.3±4.2	10.9±4.5	11.2±3.5*	15.0±4.2***	16.7±3.6***
Subscapular skinfold, mm	9.3±4.2	11.2±4.9	13.6±5.2	8.7±3.5**	12.5±4.3***	14.7±3.9***
Suprailiac skinfold, mm	5.4±2.3	6.2±2.5	6.5±3.0	7.6±3.4***	9.4±3.6***	10.1±3.1***
Abdominal skinfold, mm	9.3±4.5	11.9±5.3	14.2±5.7	11.3±5.0***	15.3±5.0***	17.2±4.1***
Body mass index, kg/m^2	16.8±3.1	19.2±3.7	20.9±3.6	16.9±3.2	20.3±3.9***	22.9±4.0***
Upper arm muscle area, cm^2	14.6±6.4	26.3±10.3	35.9±9.6	16.5±6.8***	24.9±8.9**	28.6±9.8***
Upper arm fat area, cm^2	10.0±4.8	12.7±6.1	13.8±6.9	10.8±4.6**	16.9±6.4***	19.8±5.6***
Fat percent	12.6±4.5	13.7±4.5	14.2±4.5	20.6±4.7***	24.4±4.3***	26.2±3.4***

Data presented as mean±SD.
[1]Survey years: 1999 – 2011.
[2]Survery years: 2005 – 2011.
P-value for the t-test of age specific mean between males and females.
*P<0.05; **P<0.01; ***P<0.001.

Table 4. Comparison of SES characteristics with age and sex specific cutoff point of BMI

Variable	Males (n = 1999)[1]		Females (n = 2195)[2]	
	<85 percentile n (%)	≥85 percentile n (%)	<85 percentile n (%)	≥85 percentile[3] n (%)
Father's education				
01–10 year of schooling	399 (24.0)	75 (22.9)	431 (24.8)	77 (17.7)**
11–14 year of schooling	259 (15.6)	44 (13.5)	206 (11.9)	58 (13.3)
Graduate and above	399 (24.0)	208 (63.5)	431 (24.8)	77 (17.7)
Father's occupation				
Business	758 (45.4)	153 (46.7)	704 (40.4)	161 (37.0)*
Service	874 (52.3)	166 (50.6)	990 (56.8)	251 (57.7)
Retired	38 (2.3)	9 (2.7)	48 (2.8)	23 (5.3)
Family caste				
General	1360 (81.4)	272 (82.9)	1538 (88.1)	402 (92.4) **
Other backward class	215 (12.9)	40 (12.2)	26 (1.5)	9 (2.1)
Scheduled caste	96 (5.7)	16 (4.9)	181 (10.4)	24 (5.5)
Sibling				
One	760 (45.5)	173 (52.7)*	888 (50.9)	223 (51.3)
Two	827 (49.5)	137 (41.8)	793 (45.4)	195 (44.8)
Three or more	83 (5.0)	18 (5.5)	64 (3.7)	17 (3.9)
Family member				
Three or less	465 (27.8)	116 (35.4)*	554 (31.8)	151 (34.7)
Four to five	831 (49.7)	146 (44.5)	892 (51.1)	221 (50.8)
Six or more	375 (22.4)	66 (20.1)	299 (17.1)	63 (14.5)
Toilet number				
One	1159 (70.0)	199 (61.6)*	1042 (59.8)	225 (51.7)**
Two	423 (25.5)	104 (32.2)	561 (32.2)	168 (38.6)
Three or more	75 (4.5)	20 (6.2)	141 (8.0)	42 (9.7)
Rooms Number				
1–3	718 (44.1)	121 (38.5)	704 (40.8)	152 (35.1)*
4–6	752 (46.2)	166 (52.9)	879 (50.9)	234 (54.0)
7 or more	158 (9.7)	27 (8.6)	144 (8.3)	47 (10.9)
Monthly expenditure, rupee				
Up to 5000	314 (18.8)	41 (12.5)**	214 (12.2)	42 (9.7)***
5001–10000	971 (58.1)	195 (59.5)	851 (48.8)	176 (40.5)
10001–15000	302 (18.1)	64 (19.5)	460 (26.4)	122 (28.0)
Above 15000	84 (5.0)	28 (8.5)	220 (12.6)	95 (21.8)

Data presented as n (%).
[1]Survey years: 1999–2011.
[2]Survery years: 2005–2011.
[3]Chi-square test was done to find association between SES variables and overweight in males and females separately *$p<0.05$; **$p<0.01$; ***$p<0.001$.

med and plotted by age and sex as a proxy indicator of fatness (Fig. 3).

Total skinfolds thickness increased up to 11 years of age and then it was static in males, however, it gradually increased with age in females. On average by 0.5 (0.07) and 1.66 (0.06) mm skinfold increased every year in males and females respectively (both $p<0.001$). The average fat percent calculated by skinfold thick-

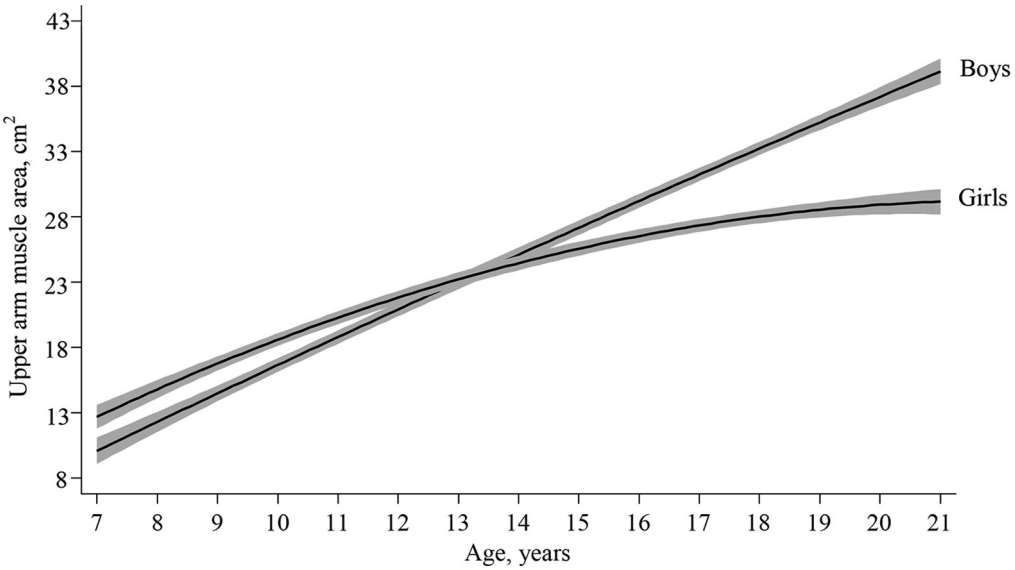

Fig. 1. Mean values for upper arm muscle area by age and sex in the study population

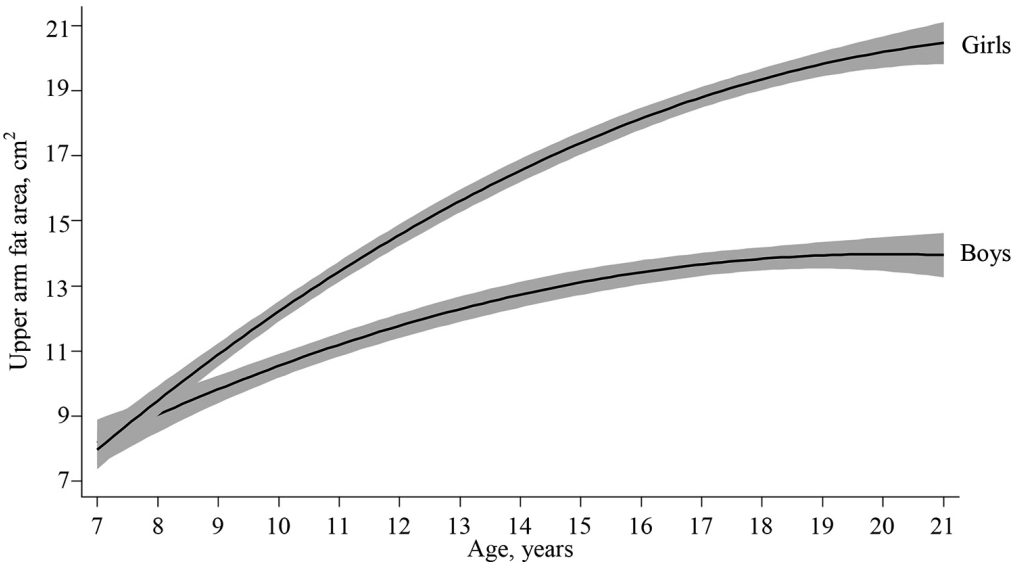

Fig. 2. Mean values for upper arm fat area by age and sex in the study population

ness was higher in females than males ($p<0.001$) at each age group is plotted in Figure 4.

Fat percent increased with age up to 14 years in males and then it was static, however, it gradually increased with age in females and increasing rate was different between males and females (0.18%, 0.02; $p<0.001$ vs 0.56%, 0.02; $p<0.001$ respectively).

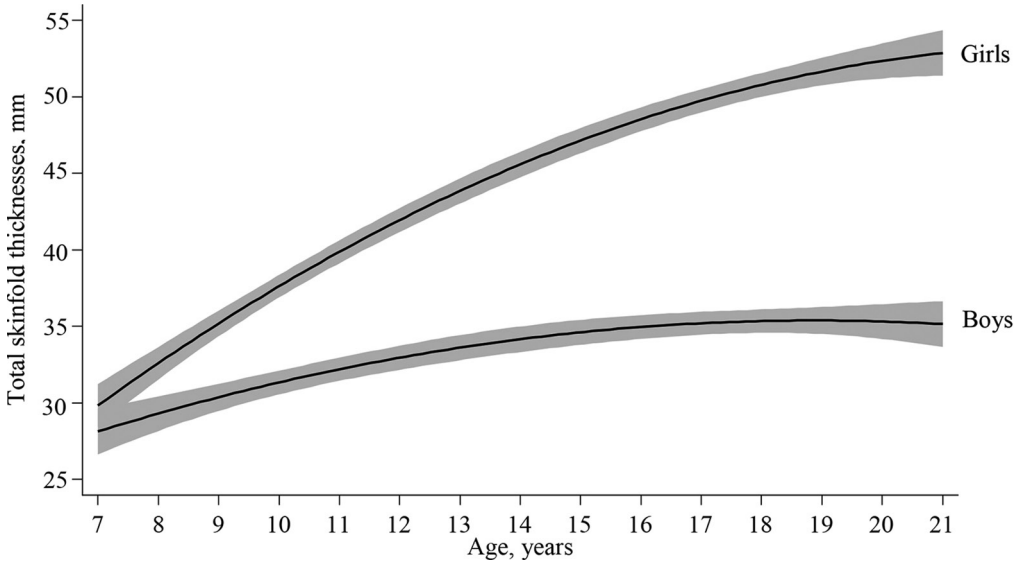

Fig. 3. Mean values for total skinfold thickness by age and sex in the study population

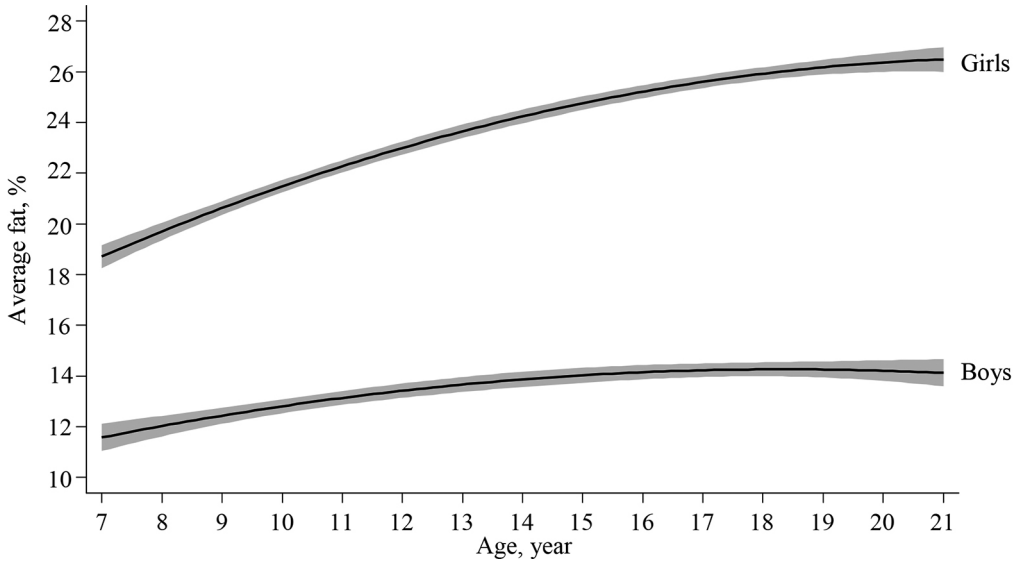

Fig. 4. Mean values for fat percent by age and sex in the study population

Discussion

Our study demonstrated to find out the status of overweight and body composition by age and sex in Asian Indian urban Bengali Hindu children, adolescents and young adults aged 7–21 years. The present study showed that the overall prevalence of overweight was 14.8%. Several studies have been done in different urban areas of India and reported the prevalence of overweight. The overall prevalence was found 25.2% aged 14–17 years (Gupta et al. 2011) and 22% aged 4–17 years (Sharma et al. 2007) in school going children from affluent families in Delhi. Ramachandran et al. (2002) reported that the prevalence of overweight was 17.8% in boys and 15.8% in girls in urban South Indian school going children aged 13–18 years. They defined overweight as BMI≥25 kg/m^2. Overweight was 27.5% and 20.9% in urban school going boys and girls respectively in Pune, Maharastra (Rao et al. 2007). Other study found 20.6% and 18.3% overweight in boys and girls respectively aged between 2 and 17 years (Khadilkar et al. 2011), which were higher than the present study. Overweight was higher in boys than girls in all above mentioned studies, however, present study did not find any difference of overweight between males and females. Age dependent overweight is reported by several studies. In Delhi school children aged 14–17 years, authors showed that overweight was 30% and 40% in boys and girls respectively at 14 years of age, and then it decreased at 17 years of age (27% in boys and 22% in girls) (Bhardwaj et al. 2008). However, Khadilkar et al. (2011) reported that overweight increased with increasing age from 2 to 17 years. The overall prevalence of overweight was 7% in age 2–5 years and 14% in age 14–17 years and there was no difference of overweight between sexes in the same age groups. We did not find changes of overweight by age group in the present study. It is explained that overweight increased with increasing age due to hormonal changes both in boys and girls (Sharma et al. 2007). Their prevalence was higher than our study because their studies were conducted mostly in urban affluent families, whereas, our study was done in urban middle class families. Food habits is also different in different part of India which might be a cause of different prevalence of overweight in Pune, Delhi, Chennai and Kolkata. Another possible explanation is selection of cut-off point of overweight. Some studies have used >25 kg/m^2 of BMI to define overweight for Asian Indian (Pandey et al. 2009), however, we used IOTF cut-off point for children and adolescents, and ≥23 kg/m^2 of BMI for adults. Studies on Caucasian children from the US did not find significant difference of overweight prevalence between sexes (Ogden et al. 2012). In comparison to our data, the prevalence of overweight was higher in low-in-income Mexican Americans adolescents (40.1%) (Lacar et al. 2000).

We estimated UAMA, UAFA and fat percent to explore in muscularity and body fat status by age and sex. In this study, mean UAMA, UAFA and fat percent were higher than reported by other two studies in West Bengal which were conducted in the district of Darjeeling. One study has been carried out in low SES area among school going children belonging to the Bengali Muslim Population (Sen et al. 2011). Another study was conducted by Debnath et al. (2017) among rural school going children, whereas, our study was conducted in

urban area in Kolkata. It is found that rural Zimbabwean children (Olivieri et al. 2008) have lower UAMA and UAFA compared to our study, although, Nigerian children have higher UAMA and lower UAFA area compared to our study (Senbanjo et al. 2014). Similarly, fat percent was lower in our study compared to Nigerian, Egyptian and Turkish children (Senbanjo et al. 2014; Monir et al. 2004; Ozturk et al. 2009). Population variations of muscularity and adiposity can be attributed to several associated factors such as sex, ethnicity, dietary intake, food habits, physical exercise patterns, SES status and burden of infectious disease, and inherited gene is also an important determinant of human morphology (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, it was observed that arm muscle was higher in males and lower in females, and body fat was higher in females and lower in males. Similar trends are documented by previous studies among Indian, Argentinean, South Korean, Kenyan, Zimbabwean, Turkish and Nigerian children (Chowdhury and Ghosh 2009; Basu et al. 2010; Sen et al. 2011; Sen and Mondal 2013; Singh and Mondal 2014; Bolzan et al. 1999; Kim et al. 1999; Semproli and Gualdi-Russo 2007; Olivieri et al. 2008; Ozturk et al. 2009; Senbanjo et al. 2014).

We found that arm muscularly increased with increasing age in both sexes, although this increment rate was higher in males than females after 14 years of age. However, arm fat, total skinfold thickness and fat percent increased with increasing age in females. Other studies reported the similar findings in Indian (Sen et al. 2011; Debnath et al. 2017), Nigerian, (Senbanjo et al. 2014), Turkish (Ozturk et al. 2009) and Zimbabwean (Olivieri et al. 2008) children. The age and sex difference of UAMA and UAFA is due to sex-hormones (Sen et al. 2011). Estrogen increases fat deposition and more fat storage in females than males. While sex hormones increases peripheral subcutaneous fat in females. On the other hand, testosterone metabolizes fat and reduces fat in males.

This study has several limitations, firstly, the survey period was different. The subjects were compared between sexes at the same age but measurement period was different. Male participants were recruited from 1999 to 2011, whereas, female participants were recruited from 2005 to 2011. Secondly, this study was carried out only in urban area and there were no representatives from rural area. Thirdly, the overweight was identified by using only BMI. Studies demonstrated that BMI underestimates overweight and obesity in Asian population (Dudeja et al. 2001; Shaikh et al. 2016). Fourthly, fat percent was estimated using Siri equation among all age groups which is developed for adult population (Siri 1956).

In spite of these limitations, our study had several strengths. We had included urban Bengali children, adolescents and young adults with good representation from different groups including age and sex. In addition, we used age and sex specific and Asian cut-off point of BMI. The equations for estimating upper arm muscle and fat areas and fat mass percent were used in Indian and Bangladeshi population previously.

In conclusion, the prevalence of overweight was same among males and females aged 7–21 years in Indian Ben-

gali Hindu Population which was lower than other cities like Mumbai, Delhi and Pune. However, fat percent estimated using skinfold thickness was higher in females than males. Fat percent increased with increasing age in females only. In addition, some SES variables and female gender associated with overweight. Both arm muscle and fat areas were higher in urban Kolkata males and females compared to rural population of North Bengal in West Bengal.

Acknowledgements

We acknowledge the Neys van Hoogstraten foundation, The Netherlands (ID158) and Indian Statistical Institute, Kolkata for their funding support of this project. Other personnel, Samrat Paul, Jahnabi Banerjee, Soma Aich, Chitrita Roychoudhury and Suhhasree Bhadra are acknowledged for their data collection in the field and technical support. We are also thankful to the students for their participation in the project and their parents to allow us to take SES information from their families.

Authors' contributions

RD, RS, SD and PD designed the research, developed project concept and research plan, designed and developed data collection plan and provided study oversight of the trial in the field; SS analyzed data, wrote the paper and had responsibility for final content. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

Corresponding author

Saijuddin Shaikh, JiVitA Project, Godown Road, Paschimpara, Gaibandha, Bangladesh
e-mail: saiju.jivita@gmail.com

References

Banerjee AV, Duflo E. 2008. What is middle class about the middle classes around the world? J Economic Perspectives 22:3–28.

Basu D, Sun D, Banerjee I, Singh YM, Kalita JG, Rao VR. 2010. Cross-sectional reference values of upper arm anthropometry of the Khasi-tribal adolescents of Meghalaya, India. Asia Pac J Clin Nutr 19(2):283–8.

Bhardwaj S, Misra A, Khurana L, Gulati S, Shah P, Vikram NK. 2008. Childhood obesity in Asian Indians: a burgeoning cause of insulin resistance, diabetes and sub-clinical inflammation. Asia Pac J Clin Nutr 17(Suppl 1):172–75.

Bolzan A, Guimarey L, Frisancho AR. 1999. Study of growth in rural school children from Buenos Aires, Argentina using upper arm muscle area by height and other anthropometric dimensions of body composition. Ann Hum Biol 26(2):185–93.

Brandy C, Büge M. 2014. A cartography of the new middle classes in developing and emerging countries. Discussion paper 35/2014, German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE).

Chhatwal J, Verma M, Riar SK. 2004. Obesity among preadolescent and adolescents of a developing country (India). Asia Pac J Clin Nut 13(3):231–5.

Chowdhury SD, Ghosh T. 2009. The upper arm muscle and fat area of Santal children: an evaluation of nutritional status. Acta Paediatr 98(1):103–6.

Christensen DL, Eis J, Hansen AW, Larsson MW, Mwaniki DL, Kilonzo B, et al. 2008. Obesity and regional fat distribution in Kenyan populations: impact of

ethnicity and urbanization. Ann Hum Biol 35(2):232–49.

Chun N. 2010. Middle class size in the past, present and future: a description of trends in Asia, Manila: Asian Development Bank.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. 2000. Establishing a standard definition for child overweight and obesity: international survey. BMJ 320(7244):1240–3.

Das R, Das S, Datta Banik S, Saha R, Chakraborty A, Dasgupta P. 2016. Secular trends in physical growth and maturation in 7 to 21 years-old Bengali males and females from Kolkata, India, over six decades of time interval. Int J Anthropol 31(3):185–226.

Debnath S, Mondal S, Sen J. 2017. 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. Anthropol Rev 80(1):85–102.

Dudeja V, Misra A, Pandey RM, Devina G, Kumar G, Vikram NK. 2001. BMI does not accurately predict overweight in Asian Indians in northern India. Brit J Nutr 86(1):105–12.

Durnin JV, Womersley J. 1974. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Brit J Nutr 32(1):77–97.

Flegal KM, Carroll MD, Ogden CL, Curtin LR. 2010. Prevalence and Trends in Obesity Among US Adults, 1999–2008. JAMA 303(3):235–41.

Ford ES, Mokdad AH. 2008. Epidemiology of obesity in the Western Hemisphere. J Clin Endocrinol Metabol 93(Suppl 1):1S–8S.

Frisancho AR. 1981. New norms of upper limb fat and muscle areas for assessment of nutritional status. Am J Clin Nutr 34(11):2540–5.

Goel K, Misra A, Vikram NK, Poddar P, Gupta N. 2010. Subcutaneous abdominal adipose tissue is associated with the metabolic syndrome in Asian Indians independent of intra-abdominal and total body fat. Heart 96(8):579–83.

Gupta DK, Shah P, Misra A, Bharadwaj S, Gulati S, Gupta N, et al. 2011. Secular trends in prevalence of overweight and obesity from 2006 to 2009 in urban Asian Indian adolescents aged 14–17 years. PLoS ONE 6(2):17221e.

He Q, Horlick M, Thornton J, Wang J, Pierson RN, Heshka S et al. 2004. Sex-specific fat distribution is not linear across pubertal groups in a multi ethnic study. Obes Res 12(4):725–33.

Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Fleqal KM. 2004. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. JAMA 291(23):2847 – 50.

Kapil U, Singh P, Pathak P, Dwivedi SN, Bhasin S. 2002. Prevalence of obesity amongst affluent adolescent school children in Delhi. Indian Pediatr 39(5):449–52.

Kelishadi R. 2007. Childhood overweight, obesity, and the metabolic syndrome in developing countries. Epidemiol Rev 29:62–76.

Khadilkar VV, Khadilkar AV, Cole TJ, Chiplonkar SA, Pandit D. 2011. Overweight and obesity prevalence and body mass index trends in Indian children. Int J Pediatr Obes 6(2):216e–24e.

Kim KB, French KE, Spurgeon JH. 1999. Somatic comparisons at four ages of South Korean females and females of other Asian groups. Am J Hum Biol 11(6):735–44.

Kotian MS, Kumar G, Kotian SS. 2010. Prevalence and determinants of overweight and obesity among adolescent school children of South Karnataka, India. Indian J Communit Med 35(1):176–8.

Lacar ES, Soto X, Riley WJ. 2000. Adolescent obesity in a low-income Mexican American district in south Texas. Arch Pediatr Adol Med 154(8):837–40.

Lissner L, Sohlstrom A, Sundblom E, Sjoberg A. 2010. Trends in overweight and obesity in Swedish school children 1999–2005: has the epidemic reached a plateau? Obes Rev 11(8):553–9.

Lobstein TJ, James WPT, Cole TJ. 2003. Increasing levels of excess weight among children in England. Int J Obes 27:1136–8.

Mahato MP, Chandra S, Bhattacharjee P. 2015. Prevalence of obesity in affluent school children of Greater Noida, Uttar Pradesh. Indian J Child Health 2:13–14.

Misra A, Khurana L, Vikram NK, Goel A, Wasir JS. 2007. Metabolic syndrome in children: current issues and South Asian perspective. Nutr 23(11):895–910.

Misra A, Vikram NK. 2004. Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications. Nutr 20(5):482–91.

Monir Z, Koura M, Erfan M, Abd El, Aziz A, Mansour M. 2004. Anthropometric parameters in relation to nutritional status in school children. Egypt Med J Nat Res Cent 5:15–39.

Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. 1992. Long-term morbidity and mortality of overweight adolescents. A follow-up of the Harvard Growth Study of 1922 to 1935. NEJM 327(19):1350–5.

NFHS. 2005. Key Findings Report, National Family Health Survey (NFHS-3). Ministry of Health and Family Welfare, Government of India. Available at: http://www.nfhsindia.org/nfhs3.html.

Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. 2010. Prevalence of High Body Mass Index in US Children and Adolescents, 2007–2008. JAMA 303(3):242–9.

Ogden CL, Carroll MD, Kit BK, Flegal KM. 2012. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. JAMA 307(5):483–90.

Olivieri F, Semproli S, Pettener D, Toselli S. 2008. Growth and malnutrition of rural Zimbabwean children (6–17 years of age). Am J Phys Anthropol 136(2):214–22.

Ozturk A, Budak N, Cicek B, Mazicioglu MM, Bayram F, Kurtoglu S. 2009. Cross-sectional reference values for mid-upper arm circumference, triceps skinfold thickness and arm fat area of Turkish children and adolescents. Int J Food Sci Nutr 60(4):267–81.

Pandey RM, Madhavan M, Misra A, Kalaivani M, Vikram NK, Dhingra V. 2009. Centiles of anthropometric measures of adiposity for 14- to 18-year-old urban Asian Indian adolescents. Metabol Synd Relat Disord 7(2):133–41.

Perini TA, de Oliveira GL, Ornellas JS, de Oliveira FP. 2005. Technical error of measurement in anthropometry. Rev Bras Med Esporte 11(1):81–5.

Ramachandran A, Snehalatha C, Vinitha R, Thayyil M, Kumar CK, Sheeba L et al. 2002. Prevalence of overweight in urban Indian adolescent school children. Diabetes Res Clin Pract 57(3):185–90.

Rao S, Kanade A, Kelkar R. 2007. Blood pressure among overweight adolescents from urban school children in Pune, India. Eur J Clin Nutr 61(5):633–41.

Roemmich JN, Rogol AD. 1999. Hormonal changes during puberty and their relationship to fat distribution. Am J Hum Biol 11(2):209–24.

Rosenheck R. 2008. Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk. Obes Rev 9(6):535–47.

Semproli S, Gualdi-Russo E. 2007. Childhood malnutrition and growth in a rural area of Western Kenya. Am J Phys Anthropol 132(3):463–9.

Sen J, Mondal N. 2013. Fat mass and fat free mass as indicators of body composition among Bengalee Muslim children. Ann Hum Biol 40(3):286–93.

Sen J, Mondal N, Dey S. 2011. Assessment of the nutritional status of children aged 5–12 years using upper arm composition. Ann Hum Biol 38(6):752–9.

Senbanjo IO, Oshikoya KA, Njokanma OF. 2014. Upper arm composition and nutritional status of school children and adolescents in Abeokuta, Southwest Nigeria. World J Pediatr 10(4):336–42.

Shaikh S, Jones-Smith J, Schulze K, Ali H, Christian P, Shamim AA et al. 2016. Excessive adiposity at low BMI levels

among women in rural Bangladesh. J Nutr Sci 5(11):1–9.

Sharma A, Sharma K, Mathur KP. 2007. Growth pattern and prevalence of obesity in affluent schoolchildren of Delhi. Public Health Nutr 10(5):485–91.

Singh J, Mondal N. 2014. Use of upper-arm anthropometry as measure of body composition and nutritional assessment in children and adolescents (6–20 Years) of Assam, Northeast India. Ethiop J Health Sci 24(3):243–52.

Singhal N, Misra A, Shah P, Rastogi K, Vikram NK. 2010. Secular trends in obesity, regional adiposity and metabolic parameters among Asian Indian adolescents in north India: a comparative data analysis of two selective samples 5 years apart (2003, 2008). Ann Nutr Metab 56(3):176–81.

Siri WE. 1956. The gross composition of the body. Adv Biol Med Phys 4:239–80.

Subramanyam MA, Kawachi I, Berkman LF, Subramanian SV. 2010. Socioeconomic Inequalities in Childhood Under-nutrition in India: Analyzing Trends between 1992 and 2005. PLoS ONE 5(6):11392e.

Thibault R, Genton L, Pichard C. 2012. Body composition: why, when and for who? Clin Nutr 31(4):435–47.

Thibault R, Pichard C. 2012. The evaluation of body composition: a useful tool for clinical practice. Ann Nutr Metab 60(1):6–16.

Tongco MDC. 2007. Purposive sampling as a tool for informant selection. Ethnobotany Research & Application 5:147–58.

Weiner JS, Lourie JA. 1969. Practical Human Biology. Academic Press Inc. Ltd., London, England.

Wells JC. 2007. Sexual dimorphism of body composition. Best Pract Res Clin Endocrinol Metab 21(3):415–30.

WHO. 2004. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363(9403):157–63.

WHO. 2000. Obesity preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization Technical Report Series 894: i–xii; 1–253.