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COMPARISON OF BODY COMPOSITION AMONG RURAL PRESCHOOL CHILDREN OF PURULIA, WEST BENGAL, USING TWO DIFFERENT EQUATIONS

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ABSTRACT:

Body composition is an important factor in identifying populations at risk of metabolic disease including type-2 diabetes in South Asian children. Many equations for calculating body-fat percentage (BF %) from anthropometric methods have been developed among South-Asian children. The objective of this study was to compare the BF % derived from two different methods obtained from skinfold equations in Santal tribal and Bauri caste preschool children. In Purulia, 1012 (480 girls, 532 boys) rural children aged 2-6 years underwent anthropometric measurements. We conducted anthropometry, including biceps, triceps, sub-scapular, suprailiac and medial-calf skinfold thicknesses. Two previously published equations (Shaikh and Mahalanabis and Slaughter et al.,) were used to calculate BF % from anthropometric data. There was poor agreement between the two BF % values. The former equation over estimated the BF (%) while the latter equation tended to under-estimate BF (%). Thus, currently available skinfold equations do not accurately predict BF % in rural preschool children of Purulia, West Bengal, India. Further studies are needed using direct methods of determining body fat. Subsequently, validation studies using skinfolds should be undertaken to determine the sex and ethnic specific equations.

Keywords: *India; Preschool children, Body composition, Skinfold, Body fat*

INTRODUCTION

In India, under nutrition and over nutrition are epidemics of the impoverished and the affluent respectively and is part and parcel of the double burden of disease in this country (Subramanian et al., 2006). According to recent National Family Health Survey (NFHS-3, 2005-2006) and (UNICEF Reports, 2007), 46% of preschool children and 30% of adults in India suffer from moderate and severe grades of protein-calorie malnutrition as judged by anthropometric indicators. Humans need a wide range of nutrients to lead a healthy and active life. Infants and young children grow rapidly and require nutrients not only for maintenance but also for growth. They require relatively more nutrients (2-3 times) per kg body weight than adults (ICMR, 2009). The increase in childhood overweight and obesity (Kumar et al., 2007; Lobstein et al., 2004; WHO, 2007) is thought to contribute to this public health problem. A review by Misra et al., (2007) concluded that abdominal adiposity and excess body fat are important risk factors for development of insulin resistance in South Asian children. Measurement of body composition in South Asian children is therefore likely to be important in identifying groups and individuals at risk of metabolic disease including type-2 diabetes. There were diverse ways of measuring body composition. Laboratory measurements are precise, involve complicated equipments and intricate measures and trained technicians. Anthropometric methods, though less accurate compared with laboratory methods, are much simpler and inexpensive, and can be carried out for different ethnic groups with ease. However, not all of them are appropriate for preschool children. An accurate, reliable and convenient way of assessing preschool children's body composition is essential for monitoring early childhood disease in our community and the nation. For assessing absolute body composition direct methods are considered to be the most accurate methods e.g. Air displacement plethysmography; under-water weighing; dual energy x-ray absorptiometry (DXA); bio-impedance analysis (BIA) thus controlling it's applied to laboratory settings. Scientists suggest the use of the skinfold method, the measurement of subcutaneous fat, in field setting as an alternative to laboratory methods. Currently it is the most widely adopted field method for measurement of body fat in children (Heyward, 1996 & 2006). Since the instruments used are portable, inexpensive and non-invasive, skinfold method can be readily applied in clinics, laboratories and schools. It also has high correlation with percent body fat (Billisari & Roche, 2005). For larger scale population/community research or screening purposes more indirect portable field methods are desirable. At present the most commonly used methods are BMI and skinfolds. These anthropometric based methods are easier, inexpensive and relatively quick to perform but are not direct measures of BF (%). BMI is a measure of overall adiposity based on weight relative to height and therefore does not give any information on body composition. Skinfold data require equations to calculate BF (%) from thickness measurements respectively. In this present study we use two skinfold equations developed in South Asian children, both using a two-compartment (2C) model Shaikh and Mahalanabis (2004) and Slaughter et al., equation (1988) for converting anthropometric measurements to BF (%). The purpose of the present study was to compare the percent body fat (BF %) predicted from two different equations using skinfold measurement in Santal and Bauri preschool children in Purulia, aged 2 to 6 years.

MATERIAL AND METHODS

Study area & population:

The present cross-sectional study was conducted in thirty villages in Purulia district of West Bengal. Since this study was among the preschooler (2-6) years of age, all preschool children and residents in the thirty villages were informed before the study and a total of 1012 (480 girls, 532 boys) individuals were measured. These villages are located 20 km from Adra railway station, which is approximately 270 km from Kolkata, the provincial capital of West Bengal. According to the 2001 census, the district contains population of 25,36,516 of whom 12,98,078 are males and 12,38,438 are females out of whom 19.35% are Scheduled Castes and 19.22% are Scheduled Tribes. Among them, Santals consist of the highest population concentration in the district. According to the report of West Bengal Scheduled Castes and Tribes Facts and Information, Special Series No. 32, 1989, Santals, among all the tribal communities of Purulia district, comprise 62.66 %. Tribal societies of Purulia are having distinct characteristics, where most of them are of Proto-Australoids groups with dark skin colour, sunken nose and lower forehead. As far as linguistic affiliation is concerned, the languages spoken by the tribes in Purulia district are mostly from Austro-Asiatic family where people belonging to Munda branch speak Santhali, Gondi, and Kheria. The Bauris are a comparatively well known sizeable caste group in West Bengal. The total Bauri population in West Bengal is 1,091,022, constituting 5.9% of the total scheduled caste population of the state. In Purulia District, the Bauri population is

209,080, constituting 8.2% of the total scheduled caste population of the district. The Bauri is a cultivating and earth-working caste. They are mainly engaged as low wage laborers in the paddy fields of the higher caste groups and in the construction of roads. Some of them are also engaged in selling various items of merchandise in trains and buses in Purulia. Their other main occupation is palanquin-bearing. The socio-economic status and literacy rate of Bauris is very low (Risley, 1981).

Ethical approval

Prior to the data collection ethical permission was obtained from the Vidyasagar Ethical Committee. Informed consent was also obtained from the parents of the children.

Anthropometric measurements and Statistics:

Skinfolds and circumference were used to measure BF (%) from which fat mass (FM, kg) and fat free mass (FFM, kg) were calculated were considered to be reference methods for the purpose of this study. The anthropometric data collections were carried out by first author (SD) (Lohman et al., 1988), skinfolds were measured using Holtain skinfold caliper and followed the standard protocol. All available (2-6 years) preschool children were measured at the time of data collection from house-to-house visit in the studied villages of Purulia, West Bengal, India. A total of 1012 (532 boys & 480 girls) preschool children were measured. Height was measured using anthropometric rod to the nearest 0.1cm; weight was measured using weighing machine to the nearest 100 g; mid-upper arm circumference (MUAC), waist circumference (WC) and hip circumference (HC) was measured using and measuring tape to the nearest 0.1cm at the middle of the acromion and olecranon. Biceps (BSF), triceps (TSF), sub-scapular (SSSF), suprailiac (SISF) and medial calf (MCSF) skinfold thickness was measured to the nearest 0.1mm using Holtain skinfold caliper. The formulae used for all derived measurements are:

Body mass index (BMI, kg/m^2): Weight (kg)/ Height $(m)^2$; (WHO, 1995).

Percent body fat (PBF, %); (Shaikh and Mahalanabis, 2004) :

$5.304 + 0.269 \times T + 0.50 \times S + 0.685 \times M - 0.063 \times A$ (For Boys)

$7.017 - 0.053 \times T + 0.201 \times S + 0.765 \times M + 0.052 \times A$ (For Girls)

Where, T= Triceps skinfold

S= Subscapular skinfold

M= Mid-arm circumference

A= Age in months

Percent body fat (PBF, %); (Slaughter et al., 1988) :

1.21 (TRSF+SSSF) −0.008 (TRSF+SSSF) 2 −3.2 (For Boys)

1.33 (TRSF+ SSSF) −0.013 (TRSF+SSSF) 2 −2.5 (For Girls)

Fat mass (FM, kg) = Body Weight (Kg) x [PBF/ 100]; (van Itallie et al., 1990).

Fat mass index (FMI, Kg / m^2) = [FM (Kg) / $Height^2$ (m^2)]; (van Itallie et al., 1990).

Body Adiposity Index (BAI) = [Hip circumference (cm) / (Height x v Height)] -18; (Bergman et al., 2011).

BMI (kg/m^2), PBF (%), FM (kg) and FMI were calculated using the equations mentioned above. Technical errors of measurements (TEM) were calculated and the results were found to be within the reference values cited by Ulijaszek and Lourie (1994). Therefore, TEM was not incorporated in statistical analyses. Student's t- test was performed to test the sex difference in applied anthropometric and derived variables. Analysis of variance (ANOVA) tests were undertaken to test for differences in the mean values of the anthropometric characteristics between the ages (2-6 years). Mean difference was also calculated to see the variability between values of PBF, FM & FMI obtained from Shaikh & Mahalanabis (2004) and Slaughter et al., (1988). All statistical analyses were performed using the Statistical Package for Social Science (SPSS/PC- Version 16). Statistical significance was set to a value of $p < 0.05$.

RESULTS

Results showed that there existed positive significant sex difference in weight (t= 2.155, p< 0.05) at age 2 years; biceps skin fold (t= 2.031, p< 0.05) at age 3 years; BMI (t= 2.969, p<0.05) at age 2 years; (t= 1.956, p< 0.05) at age 3 years and (t= 2.759, p< 0.01) at age 6 years.

Similarly, negative significant sex difference in hip circumference (t= -2.662, p< 0.01) at age 6 years; biceps skin fold (t= -3.133, p< 0.01) at age 6 years; triceps skin fold (t= -2.957, p< 0.01) & (t= -3.893, p< 0.001) at age 5 and 6 years; sub-scapular skin fold (t= -2.510, p<0.01) at age 6 years; suprailiac skin fold (t= -2.147, 0.05), (t= -3.118, p< 0.05) and (t= -4.216, p< 0.001)

Table 1 (a): Age and sex – specific means (SD), t-test and F-test values of anthropometric variables.

Variables	Sex	Age (Years)					F
		2	3	4	5	6	
Weight (kg)	Boys	10.4 (1.7)	11.3 (1.4)	13.2 (2.0)	15.0 (2.4)	16.8 (2.3)	137.9***
	Girls	10.3 (2.0)	11.4 (1.9)	12.9 (2.2)	14.4 (2.1)	16.4 (2.2)	104.2***
	t	0.159	-0.326	1.105	2.155*	1.275	
Height (cm)	Boys	83.0 (7.0)	87.1 (8.7)	96.0 (7.2)	103.4 (6.6)	109.1 (6.5)	196.1***
	Girls	85.0 (9.4)	89.7 (8.4)	95.6 (9.5)	102.4 (7.5)	109.5 (6.4)	112.1***
	t	-1.621	-1.727	0.001	1.127	-0.433	
MUAC (cm)	Boys	13.2 (0.9)	13.3 (0.7)	14.0 (0.8)	14.1 (0.9)	14.5 (3.5)	8.2***
	Girls	13.1 (1.0)	13.3 (0.7)	13.9 (1.0)	14.2 (0.9)	14.5 (0.9)	34.6***
	t	0.681	-0.697	0.249	-1.030	-0.040	
Waist Circumference (cm)	Boys	44.6 (2.9)	45.5 (2.4)	46.5 (5.9)	48.5 (2.4)	49.5 (2.6)	27.4***
	Girls	44.8 (2.6)	45.6 (2.8)	46.6 (2.9)	48.2 (2.6)	49.6 (2.5)	40.4***
	t	-0.457	-0.263	-0.151	1.149	-0.471	
Hip Circumference (cm)	Boys	45.5 (3.2)	45.8 (4.9)	48.2 (2.7)	50.1 (2.7)	50.6 (5.1)	31.5***
	Girls	45.7 (3.0)	46.3 (2.9)	48.2 (3.0)	50.4 (2.6)	52.2 (2.9)	69.2***
	t	-0.481	-0.865	0.088	-1.008	-2.662**	
Biceps Skinfold (mm)	Boys	4.2 (1.0)	4.5 (1.0)	4.2 (1.0)	4.0 (1.0)	3.4 (0.8)	14.5***
	Girls	4.0 (1.0)	4.2 (1.2)	4.5 (1.2)	4.1 (1.3)	3.9 (1.1)	2.9**
	t	0.725	2.031*	-1.747	-0.685	-3.133**	
Triceps Skinfold (mm)	Boys	6.8 (1.8)	7.1 (1.2)	7.1 (1.6)	6.3 (1.5)	5.5 (1.1)	17.9***
	Girls	6.9 (1.4)	7.3 (1.6)	7.5 (1.9)	7.0 (1.9)	6.2 (1.4)	7.1***
	t	-0.336	-0.831	-1.596	-2.957**	-3.843***	
Subscapular Skinfold (mm)	Boys	4.8 (1.1)	5.2 (1.1)	5.2 (1.2)	5.1 (1.2)	4.7 (1.2)	4.1***
	Girls	5.1 (1.0)	5.4 (4.9)	5.3 (1.5)	4.9 (0.9)	5.1 (1.3)	0.67
	t	-1.744	-0.545	-0.651	1.587	-2.510**	
Suprailiac Skinfold (mm)	Boys	5.5 (1.6)	5.2 (1.6)	5.2 (1.3)	4.9 (1.5)	4.3 (1.2)	7.4***
	Girls	5.4 (1.1)	5.5 (1.4)	5.7 (1.8)	5.6 (1.4)	5.1 (1.5)	1.7
	t	0.529	-1.394	-2.147*	-3.118**	-4.216***	
Medial Calf Skinfold (mm)	Boys	7.8 (1.6)	7.6 (1.2)	7.5 (1.4)	6.7 (1.3)	6.4 (1.3)	16.8***
	Girls	7.8 (1.4)	7.6 (1.3)	7.6 (1.5)	7.2 (1.4)	6.8 (1.5)	6.1***
	t	0.028	-0.097	-0.491	-2.960**	-2.130*	

Significance level: ***p<0.001; **p<0.01; *p<0.05

Table 1(b): Age and sex – specific means (SD), t-test and F-test values of derived variables.

Variables	Sex	Age (Years)					F
		2	3	4	5	6	
BMI (kg/m^2)	Boys	15.1 (1.9)	15.4 (5.3)	14.3 (1.1)	14.0 (1.4)	14.1 (1.3)	5.1***
	Girls	14.3 (1.6)	14.1 (1.4)	14.3 (3.6)	13.7 (1.5)	13.6 (0.9)	4.1***
	t	2.969**	1.956*	1.787	1.498	2.759**	
PBF (%)(Slaughter et al., 1988)	Boys	9.5 (1.8)	10.0 (1.4)	10.0 (1.8)	9.4 (1.7)	8.5 (1.4)	13.1***
	Girls	13.8 (1.5)	14.4 (3.8)	14.4 (2.3)	13.8 (1.9)	13.3 (1.8)	3.2**
	t	-17.410***	-10.557**	-15.321***	-18.594***	-21.110***	
FM (kg)	Boys	1.0 (0.3)	1.3 (0.2)	1.3 (0.3)	1.4 (0.3)	1.4 (0.3)	36.7***
	Girls	1.4 (0.3)	1.6 (0.3)	1.9 (0.4)	2.0 (0.4)	2.2 (0.4)	31.6***
	t	-10.559***	-7.760***	-10.389***	-12.226***	-13.659***	
FMI	Boys	1.4 (0.4)	1.5 (0.4)	1.4 (0.3)	1.3 (0.3)	1.2 (0.3)	11.3***
	Girls	2.0 (0.3)	2.0 (0.5)	2.0 (0.5)	1.9 (0.4)	1.8 (0.3)	4.7***
	t	-10.712***	-8.005***	-10.600***	-13.152***	-14.429***	
BAI	Boys	42.8 (7.7)	39.8 (13.6)	33.6 (4.6)	29.8 (3.6)	26.6 (5.1)	66.3***
	Girls	41.2 (7.4)	37.1 (6.6)	34.5 (10.4)	31.0 (4.3)	27.7 (3.3)	75.3***
	t	1.434	1.805	-0.821	-2.265*	-1.856	

Significance level: ***p<0.001; **p<0.01; *p<0.05

Table 2: Overall age-combined sex-specific mean, SD and t-test values of all variables.

Variables	Gender	N	Mean	Std. Deviation	t
Weight (kg)	Boys	532	13.509	3.0585	2.061*
	Girls	480	13.119	2.9539	
Height (cm)	Boys	532	96.591	11.6130	-0.177
	Girls	480	96.722	11.7649	
MUAC (cm)	Boys	532	13.845	1.8076	0.125
	Girls	480	13.833	1.0166	
Waist Circumference (cm)	Boys	532	47.058	3.9593	0.247
	Girls	480	47.002	3.1708	
Hip Circumference (cm)	Boys	532	48.236	4.2848	-1.541
	Girls	480	48.627	3.7461	
Biceps Skinfold (mm)	Boys	532	4.068	1.0363	-1.113
	Girls	480	4.146	1.1842	
Triceps Skinfold (mm)	Boys	532	6.550	1.5746	-4.022***
	Girls	480	6.966	1.7193	
Subscapular Skinfold (mm)	Boys	532	5.008	1.1679	-1.359
	Girls	480	5.172	2.5078	
Suprailiac Skinfold (mm)	Boys	532	5.014	1.4984	-4.687***
	Girls	480	5.450	1.4547	
Medial Calf Skinfold (mm)	Boys	532	7.168	1.4710	-2.446*
	Girls	480	7.393	1.4427	
BMI (kg/m^2)	Boys	532	14.4280	2.00873	4.360***
	Girls	480	13.9462	1.42734	
PBF (%)	Boys	532	9.4950	1.71763	-33.688***
	Girls	480	13.9216	2.43596	
FM (kg)	Boys	532	1.2714	.32617	-20.427***
	Girls	480	1.8230	.52043	
FMI	Boys	532	1.3766	.33771	-23.896***
	Girls	480	1.9497	.42457	
BAI	Boys	532	34.0492	9.46776	-0.448
	Girls	480	34.3093	8.94485	

Significance level: ***p<0.001; **p<0.01; *p<0.05

at age 4, 5 & 6 years; medial-calf skin fold (t= -2.960, p<0.01) & (t= -2.130, p<0.01) at age 5 & 6 years; percentage body fat (t= -17.410, p<0.001), (t= -10.557, p<0.001), (t= -15.321, p< 0.001), (t= -18.599, p< 0.001) & (t= -21.110, p<0.001) at ages 2 to 6 years; fat mass index (t= -10.712,

$p<0.001$), ($t= -8.005$, $p<0.001$), ($t= -10.600$, $p< 0.001$), ($t= -13.152$, $p< 0.001$) & ($t= -14.429$, $p<0.001$) at ages 2 to 6 years; body adiposity index ($t= -2.265$, $p< 0.05$) at age 5 years.

Table 3 (a): Comparative means of PBF, FM & FMI among studied preschool boys using Shaikh & Mahalanabis (2004) and Slaughter et al., (1988) equations.

Variable	Comparative means	Age (years)				
		2 (n1= 94; n2= 85)	3 (n1= 93; n2= 106)	4 (n1= 114; n2= 86)	5 (n1= 127; n2=109)	6 (n1= 104; n2= 94)
Boys						
PBF (%)	Shaikh and Mahalanabis	17.07	16.62	16.36	15.45	14.52
	Slaughter et al.,	9.53	10.02	10.04	9.44	8.46
	Mean Difference	7.54	6.60	6.32	6.01	6.06
FM	Shaikh and Mahalanabis	1.77	1.88	2.17	2.32	2.46
	Slaughter et al.,	0.99	1.13	1.32	1.41	1.43
	Mean Difference	0.78	0.75	0.85	0.91	1.03
FMI	Shaikh and Mahalanabis	2.57	2.47	2.35	2.16	2.06
	Slaughter et al.,	1.44	1.49	1.44	1.32	1.20
	Mean Difference	1.13	0.98	0.91	0.84	0.86

Table 3 (b): Comparative means of PBF, FM and FMI among studied preschool girls using Shaikh and Mahalanabis (2004) and Slaughter et al., (1988) equations.

Variable	Comparative means	Age (years)				
		2 (n1= 94; n2= 85)	3 (n1= 93; n2= 106)	4 (n1= 114; n2= 86)	5 (n1= 127; n2=109)	6 (n1= 104; n2= 94)
Girls						
PBF (%)	Shaikh and Mahalanabis	18.94	19.80	20.85	21.62	22.58
	Slaughter et al.,	13.78	14.36	14.42	13.76	13.26
	Mean Difference	5.16	5.44	6.43	7.86	9.32
FM (kg)	Shaikh and Mahalanabis	1.96	2.26	2.70	3.11	3.72
	Slaughter et al.,	1.42	1.64	1.87	1.98	2.18
	Mean Difference	0.54	0.62	0.83	1.13	1.54
FMI	Shaikh and Mahalanabis	2.70	2.80	2.93	2.97	3.09
	Slaughter et al.,	1.97	2.03	2.04	1.89	1.82
	Mean Difference	0.73	0.77	0.89	1.08	1.27

ANOVA revealed that there existed significant age difference ($p < 0.001$ and $p < 0.01$) in all anthropometric as well as derived variables except for subscapular and suprailiac skinfolds among girls.

Table 2 shows positive significant sex difference existed in weight ($t = 2.061$, $p < 0.05$) and BMI ($t = 4.360$, $p < 0.001$). Similarly negative significant sex difference existed in TSF ($t = -4.022$, $p < 0.001$), SISF ($t = -4.687$, $p < 0.001$), MCSF ($t = -2.446$, $p < 0.05$), PBF ($t = -33.688$, $p < 0.001$), FM ($t = -20.427$, $p < 0.001$) and FMI ($t = -23.896$, $p < 0.001$).

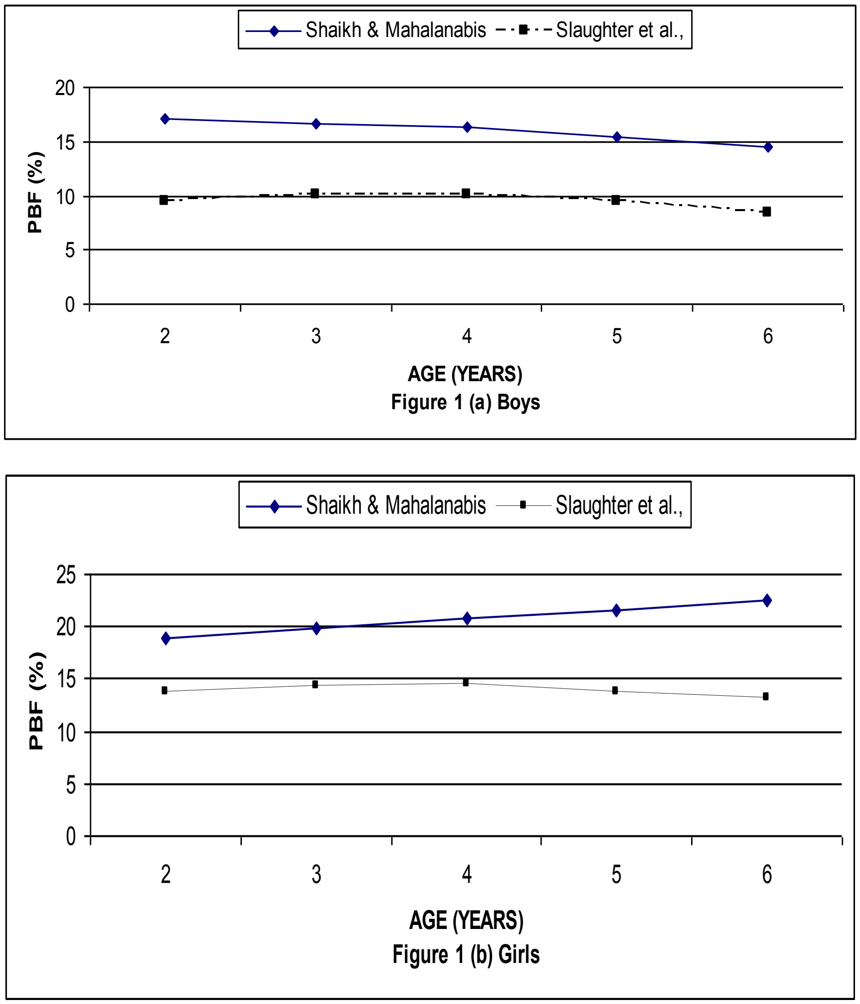
In Table 3 (a , b) and *Figure 1(a, b)* age and sex specific mean showed that the mean values was higher using Shaikh and Mahalanabis equation as compared with Slaughter et al., formula. There existed considerable difference for mean values for all body fat variables in all ages. The dispersion was more among the boys than girls.

The present study demonstrated that different values of body composition measures were obtained using the two equations. In other words, the mean values of body composition variables were not concordant.

DISCUSSION

Unhealthy body composition has an immediate and long-term negative impact on children. Adult diseases, such as *non-insulin-dependent diabetes mellitus* (NIDDM) and cardio vascular diseases (CVD) are now increasingly showing up in our youth. Socialization and early learning patterns are affected negatively and can last a lifetime. Adolescent obesity itself usually continues into adulthood perpetuating the high risk for many preventable diseases (Dietz, 1998; Guo and Chumlea, 1999). A study in Caucasian children has shown the difference in fat distribution between boys and girls increases with sexual maturity (Taylor et al., 2009). Shaikh and Mahalanabis (2004) equation BF (%) ranged in a linear fashion from under-estimation to overestimation. The Shaikh and Mahalanabis (2004) studied participants were preschool children who have had a range of BF (%) narrower than older children, and perhaps the equation was developed using BIA as the reference method. The Slaughter et al., (1988) equation that was developed in Caucasian and African American children living in the USA tended to underestimate BF (%) for most of the Indian children. The Slaughter et al., (1988) equation was published over twenty years ago, since when children in most populations have become more adipose. Indians have been shown to have

Figure 1 (a & b): Age trends in PBF (%) among studied children using Shaikh and Mahalanabis and Slaughter et al.,



relatively increased abdominal fat, including subcutaneous as well as intra-abdominal fat, compared with Caucasians (Raji et al., 2001). Limitations of the present study was the lack of any direct method (DXA, BIA etc.) of estimating BF (%) to validate the equations used by us to determine which one is the better equation for estimating the same in our study population. Though, when considering skinfold as a tool for large studies it should be pointed out that it is a technically difficult measurement and preschool children in particular can be less submissive.

However, limitations are there with direct methods also. A study in 5-21 year olds found that the bias of BF (%) measurements obtained from DXA varies according to gender, size and BF (%) (Williams et al., 2006). It was evident that the distribution of fat can influence the accuracy of DXA that is of particular relevance to the Indian population as it was evident that their fat was more centrally distributed than white Caucasians (Krishnaveni et al., 2005).

CONCLUSIONS

An important finding of the present study was that using the two different equations, divergent results were obtained. We hypothesize that the lower mean values of body fat variables obtained by using Slaughter et al., (1988) equation could be due to the fact that these equations were formulated among American subjects who had better nutritional status and thus more adiposity compared to the present subjects. Similarly, the greater mean values obtained by using (Shaikh & Mahalanabis, 2004) was probably could be due to poorer nutritional status and hence less adiposity among the children.

We therefore conclude that both these equations may not be appropriate and applicable to these ethnic groups of Purulia. Since India is a land of great ethnic heterogeneity, we recommend that ethnic-specific skinfold equations be developed. These equations can later be validated with direct methods of fat estimation.

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