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BODY COMPOSITION AND FAT PATTERNING AMONG ADOLESCENT BHIL GIRLS OF DISTRICT UDAIPUR, RAJASTHAN

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ABSTRACT

The aim of the present cross-sectional study is to describe age related changes in the body composition and fat patterning among 169 adolescent Bhil girls ranging in age from 9 to 16 years, living in various villages of district Udaipur, Rajasthan. In all 13 anthropometric measurements were taken on the subjects using standardized anthropometric techniques. These included height, weight, four circumferences (upper arm, waist, hip and calf), five skinfolds (biceps, triceps, subscapular, suprailiac and calf) and two diameters (femur bicondylar and humerus bicondylar). To study body composition, indices like body mass index, mean skinfold thickness, fat mass index and fat free mass index were gauged statistically. Rural adolescent girls of Udaipur exhibited their growth spurt in height and weight between 10 to 11 years and 13 to 14 years, respectively. Mean values of BMI increased with rapid pace from 10 to 14 years indicating overall better growth in this period. ANOVA revealed significant differences between age groups for all the measurements. Percent fat increased rapidly from 10 years till 16 years. Grand mean thickness also depicted an overall increasing trend from 10 to 16 years. Waist hip ratio decreased from 0.81 at 9 years to 0.75 at 16 years depicting greater deposition of fat in the hip region as compared to waist. Subscapular to triceps ratio indicated greater deposition of fat on the extremities till 12 years, where after trunkal fat increased at a greater pace. Waist height ratio fluctuated between a very narrow range 0.37 and 0.39 (<0.5) showing that Bhil girls were lean. A body adiposity index (ABSI) showed decline in values from 10 to 14 years followed by an increase till 15 years showing lower values of waist circumference for height and weight. Body adiposity index showed a general trend of decrease with the maximum increases between 11 to 12 and 15 to 16 years. The study concludes that Bhil girls gain greater amount of fat free mass as compared to fat mass throughout the adolescence. Their fat distribution pattern starts emerging during puberty.

Keywords: Adolescence, body composition, Body Mass Index, Fat Mass Index, Fat Free Mass Index, A body shape index.

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INTRODUCTION

Assessment of body composition includes the amount and distribution of body fat, composition of fat mass fat (FM) and fat free mass (FFM) and has important health implications for children and adolescents in clinical and population based studies (Wells and Fewtrell, 2006; Rosa *et al*., 2007). Adolescence is transitional period separated from both early childhood and adulthood. A new phase of growth occurs at adolescence with various hormonal, physiological, morphological, psychological and cognitive changes occurring in the human body. Pubescence is followed by adolescence. Height, weight, fat free mass, bone mass and bone mineral content, all increase to bring about a drastic change in body composition and shape in both the sexes during adolescence. The amount of body fat differs with age, sex, physical activity, ethnicity, nutritional status, environmental conditions, social factors and genotype (Eveleth and Tanner, 1990; Rolland Cachera, 1993; Kagawa *et al*., 2009). Body composition changes dramatically when puberty appears and therefore, the amount of body fatness and its distribution pattern appears to be more strongly related to gender and pubertal development. Genetic and environmental factors determine the final shape of the body. Body composition and fat patterning can be assessed with the help of Body mass index, percent body fat, fat mass index, fat free mass index and using ratios of various circumferences and skinfolds (Van Itallie *et al*., 1990; Good *et al*., 1999; Fiori *et al*., 2000; Wells, 2001). Goon and Tech (2013) confirmed that fatness and the fat patterning are independent anatomical characteristics of body composition. Waist circumference and waist-hip ratio are the indicators of abdominal adiposity and have been shown to be better than body mass index, an indicator of total adiposity, for identifying individuals at higher risk of developing atherosclerotic diseases (Daniels *et al*., 2000). A new index of adiposity (Body adiposity index) uses measurements of hip circumference and height (Bergman *et al.,* 2011). A body shape index (ABSI) based on waist circumference that is independent of height and body mass was developed by Krakauer & Krakauer (2012) to predict health and mortality risk. Individuals having very high ABSI are at more than double the average risk of mortality and those with very low ABSI are likely to have less risk than with average values. Very few studies have examined the association of these new indices of obesity with various anthropometric measurements and indices among adolescents.

Researchers have undertaken many studies on adolescents from different regions, caste groups and communities including tribal groups to ascertain differences in their body composition and fat patterning (Indech *et al*., 1991; Johnston *et al*., 1991; Talwar *et al.,* 2001; Mukhopadhyay *et al*., 2005; Sinha and Kapoor, 2005; Talwar *et al*., 2005, 2011; Rajkumari *et al*., 2012; Khadgawat *et al*., 2013**;** Sharma *et al*., 2013; Gaur and Kaur, 2016). Bhasin & Jain (2007) published a series of research papers on anthropometric characteristics, nutritional status and somatotypes of six tribal populations of Rajasthan including Bhils yet data on body composition and fat patterning of Bhils are lacking especially in terms of newly devised indices.

Therefore, the aim of the present study is to fill this gap and to ascertain age changes in the body composition and fat patterning of Bhil girls from 9 to 16 years.

MATERIALS AND METHODS

The present study has been undertaken with the view to study the body composition and fat patterning among adolescent Bhil Girls residing in the various villages namely Wara, Kanela, Dheekli, Mero-Ka-Gurha, Bohro-Ka-Gurha tehsil of Udaipur District of Bargaon tehsil which is 6 km towards north from Udaipur while 388 km towards north from Jaipur. Bhils constitute 45% of the total tribal population of the Rajasthan. Bhil tribe is the third largest tribal group of India next to Gonds and Santhals.

The data were collected by the second author from Government middle school, Wara, Government primary school and Government senior secondary school, Mehron-Ka-Gurha, Udaipur and some subjects were also taken from the houses located in villages; Kanela, Dhinkali, Mehron-Ka-Gurha, Boron-Ka-Gurha. Data were collected from those only who were mentally and physically normal and disease free. The age of each of the subjects was recorded after verifying the same from the school records. The age was then converted to decimal age by using the decimal age calendar of Tanner *et al* (1966). Subjects ranging in age from 9 to 16 years were divided into age groups of one year each using age mid points. Thus, each age group included individuals not more than 6 months younger or older than the age group. The general information about subject's families like educational status and occupational status, family structure was also collected through interview based schedule. To assess the growth status and fat distribution pattern of adolescent Bhil girls, thirteen anthropometric measurements were taken using the techniques given by Weiner and Lourie (1969). These include stature, weight, bicondylar humerus diameter, bicondylar femur diameter, upper arm circumference, calf circumference, waist circumference, hip circumference, biceps skinfold, triceps skinfold, subscapular skinfold, supra-iliac skinfold and calf skinfold thickness. One-way analysis of variance (ANOVA) was performed for each variable to study age trends. To study total adiposity, body mass index Wt (kg)/Ht (m^2) was calculated for each subject. A body shape index (ABSI) was calculated to study risk from high WC (Krakauer & Krakauer, 2012). A new index of obesity (Body Adiposity Index) based on hip circumference and height was also evaluated (Bergman *et al*., 2011). For studying the fat patterning, waist/hip ratio and ratio of subscapular to triceps skinfold were estimated. To study annual increments mean of the preceding age group were subtracted from the mean of the succeeding age group (Tanner 1962). Body density was calculated using equations given by Durnin and Rahaman (1967). Percentage of body fat was calculated using equation of Siri (1956). Fat mass and, fat free mass were calculated. Fat mass index (FMI) [Fat Mass (Kg)/ Height^2 (m)] and the fat free mass index (FFMI) [fat free mass (Kg)/Height^2 (m)] were calculated to study the contribution of fat mass and fat free mass in BMI (Van Itallie *et al*., 1990; Wells, 2001).

All the subjects were vegetarian but the males in their family were non-vegetarians. The staple diet of the subjects included wheat, rice, pulses and seasonal vegetables. Their main livestock is goat and very few subjects consumed goat's milk. Respondents consumed fruits occasionally. The famous food item was Dal Bati Choorma. The meals varied from three to four times a day. The students of government schools were taking mid day meal at 11:00 a.m. in schools. They ate four meals a day. Majority of the girls used to take tea with bread in the morning and chapattis with pickle or bread in the evening. At dinner time, they had chapattis with seasonal vegetables or pulses.

The general information about the socio-economic status of the subjects was measured in terms of educational and occupational status of their parents through interview schedule. 55.03% fathers and 89.35% mothers were found to be illiterate. 18.34%fathers and 4.14% mothers were literate. 21.89% fathers and 4.73% mothers had education up to primary level. 1.18% fathers and mothers were educated up to middle standard. Only 2.96% fathers and 0.59% mothers were matriculates. Father of only one subject was (0.59%) educated up to higher secondary. Majority (79.88%) of fathers were working as labourers and majority of mothers (63.31%) were engaged in farming. 30.18% mothers were housewives. 20.20% fathers and 6.51% mothers were involved in others activities like carpenters, masons, peons, sweepers, cook in the schools. They belonged to low middle socio-economic class.

RESULTS

Mean, Standard deviation and ANOVA of various anthropometric measurements of Bhil girls have been presented in Table 1. It is evident from this table that all the measurements of adolescent Bhil girls of district Udaipur, Rajasthan increased with the advancing age. Adolescent Bhil girls showed a net increase of 22.87 cm in stature over a period of eight years (initial mean 127.71cm and max. 150.58cm), witnessed their growth spurt for stature between 10 and 11 years with maximum gain of 8.14 cm. Their weight increased by 16.95 kg during this period with maximum increase of 5.29 kg between 13 and 14 years. All the circumferences showed faster growth after 10 years with maximum gain between 10 and 11 years (1.43 cm) for upper arm circumference; 11 to 12 years for waist circumference (2.14 cm); 15 to 16 years for hip circumference (5.66 cm) and from 10 to 11 years for calf circumference (2.22cm). Subscapular and suprailiac skinfold thicknesses witnessed an increasing trend after 10 years till 16 years except for minor decrease at 14 years. Both these truncal skinfolds showed maximum increase between 13 and 14 years. Biceps skinfold thickness also exhibited increasing trend till 14 years, registering maximum gain of 0.29 mm between 13 and 14 years followed by a fluctuating trend till 16 years. Triceps skinfold thickness of Bhil girls witnessed an increasing trend till 12 years showing maximum gain of 1.22 mm between 11 and 12 years. This thickness decreased till 15 years where after it increased with rapid pace till 16 years. Calf skinfold also increased regularly till 13 years followed by decrease till 15 years and

showed maximum gain of 1.03 mm between 15 and 16 years. ANOVA revealed significant differences between age groups for all these measurements.

Descriptive statistics of percent body fat, fat mass, fat free mass, various indices of body composition and fat patterning of Bhil girls have been presented in Table 2. Percent body fat among Bhil girls decreased from 9 to 10 years and increased rapidly till 16 years showing maximum gain of 1.26% between 11 and 12 years followed by 15-16 years (1.22%). After an initial decrease till 10 years, their fat mass increased rapidly till 16 years with minor decrease at 15 years. Maximum gain of 1.07 kg was seen between 15 and 16 years. Fat free mass also depicted an initial decrease from 19.14 kg at 9 to 18.30 kg at 10 years and increased regularly from 10 to 16 years with minor decrease at 15 years, showing maximum gain of 4.30 kg between 13 and 14 years. Grand mean thickness also exhibited similar trend as that of percent fat i.e. an initial decrease and rapid increase from 10 to 16 years registering maximum gain of 3.00 mm from 15 to 16 years and 2.93 mm between 11 and 12 years. After an initial decrease there is continuous increase of BMI between the age group of 10 (13.2kg/m^2) to 14 (17.59 kg/m^2) years with maximum gain in this index between 13 and 14 years (2.08 kg/m^2) followed by a minor decrease at 15 years after which it again increased.

Fat mass index in the present study increased with advancing age. The minimum mean value for fat mass index was 2.21 kg/m^2 at 10 years and its maximum value was 3.61 kg/m^2 at 16 years. Maximum gain of 0.41 kg was observed between 13 and 14years.

Fat free mass index showed a rapid increase from 10 years till 14 years followed by a gradual decrease till 16 years. The minimum mean value for this index was 11.05kg/m^2 at 10 years and maximum value of 14.13 kg/m^2were observed at 14 years with maximum gain of 1.67 kg/m^2 between 13 and14 years.

Waist height ratio fluctuated between a very narrow range of 0.37 and 0.39 (<0.5). A body shape index (ABSI) showed decline in values from 10 to 14 years followed by an increase thereafter. Body adiposity index showed an overall decreasing trend with maximum increases between 11 to 12 and 15 to 16 years. Waist hip ratio decreased from 0.81 at 10 years to 0.75 at 16 years depicting greater deposition of fat in the hip region as compared to waist region. Subscapular/ triceps ratio showed a decrease in the mean values from 0.97 at 9 years till 0.86 at 12 years showing greater deposition of extremity fat where after the values increased till 15 years showing greater trunkal fat. ANOVA revealed significant differences between age groups for all the indices except for Grand mean thickness, fat mass index, Body adiposity index and waist height ratio (Table 2).

Table 3 shows Age wise and total correlation of percent body fat and BMI with various indices. Percent body fat was found to be significantly and positively correlated with body mass index (0.61*), fat free mass index (0.44*), Waist- Height ratio (0.31*), Subscapular-triceps ratio (0.19*) and body adiposity index (0.36*).

Negative but significant correlations were observed between % body fat and waist hip ratio (-0.29*) and ABSI (-0.24*).

It is also clear from the table that BMI showed significant association with fat mass (r =0.83*), fat free mass (r =0.89*) and fat free mass index (r =0.98*) but non-significant correlation was observed between BMI and FMI.

DISCUSSION

Fat mass and fat free mass are important indicators of body composition which differ with age, sex, environmental conditions and genetic potential. Assessment of body composition and regional distribution of fat is of utmost interest to nutritionists, physical anthropologists and clinicians and has implications in metabolic disorders. Evaluation of body composition of children and adolescents is necessary as it provides an opportunity for screening their health status in terms of under nutrition and over nutrition. Such studies provide scope for timely interventions in either case.

The results of the present study clearly indicate that adolescent Bhil girls showed a net increase of 22.87 cm in stature and 16.95 kg of weight over a period of eight years. They witnessed their growth spurt for stature between 10 and 11 years and for weight between 13 and 14 years with maximum gain of 8.14 cm in stature and 5.29 kg in weight. Their body mass index showed faster growth from 10 to 14 years with maximum gain between 13 to 14 years (2.08kg/m^2). Nutrition affects fatness and stature. Significant weight gain occurs during adolescence due to rapid deposition of fat mass and fat free mass which is reflected in the increases witnessed in BMI during adolescence. Body mass index is influenced by various factors including age, sex, socio-economic condition, diet, exercise and metabolic function (Reddy, 1998). Bhil girls of the present study exhibited very low values of BMI from 9 to 16 years (less than 18 even at higher age groups) pointing towards extreme thinness and underweight. It is also evident from their waist height ratio which fluctuated between a very narrow range 0.37 and 0.39 (<0.5). Because of important physiological differences between an adult and a growing body it is pertinent to examine if the anthropometric characteristics associated with percent adiposity are different at younger ages. Bhil girls showed a net gain of 9.63 mm in grand mean thickness and 4.49 in % fat over a period of eight years. When compared with references of percentage body fat in North Indian children aged 7 to 17 years given by Khadgawat *et al* (2013), percent body fat of Bhil girls at 9 years lied at 10th percentile and between 10 to 15 years, it lied between 3rd and 10th percentile. At 16 years, their body fat percentage was less than 3rd percentile. Bhil girls possessed very less fat. They gained a total of 4.5 kg of fat during 10 to 16 years out of which 3.57 kg is gained between 10 to 14 years and maximum fat mass was gained (1.07 kg) between 15 and 16 years. The net increase in fat mass index was 1.4kg/m^2 out of which max gain of 0.41 kg was observed between 13 and 14 years. Bhil girls added 12.44 kg of fat free mass from 10 to 16 years, out of which maximum gain of 4.30 kg was witnessed between 13 and 14 years. Fat free mass index registered a

net increase of 3.08 kg/m^2 from 10 to 14 years followed by a decrease till 16 years. Maximum gain (1.67 kg/m^2) in FFMI was witnessed between 13 and14 years. According to Norgan, (1998) muscle mass among girls show increases from 40-45% between 5 to 13 years and then falls slightly because comparatively more adipose tissue is gained in adolescence. Moreover, the composition of the skeleton also changes due to deposition of mineral in cartilage. Similar findings have been reported by the present study. Bhil girls of the present study gained 61.8% of lean body mass from 10 to 14 years after which it falls till 15 years and rises again. Although normally girls gain fat mass as well fat free mass all through adolescence yet the fraction of fat mass is more among them. In the present study girls add more in muscles as compared to fat mass which may be attributed to their dietary pattern and life style. It becomes evident from the study that fat free mass contributes more towards the BMI of Bhil girls as compared to fat mass. It is also apparent from the highly significant and positive association of BMI with fat free mass index (r =0.98*) followed by fat free mass (r =0.89*) and fat mass (r =0.83*).

Body adiposity index showed a general trend of decrease with maximum increases between 11 to 12 and 15 to 16 years. As compared to percent fat it showed exaggerated values in Bhil girls. Body adiposity index is not able to predict % fat in children and over estimates % fat (El Aarbaoui *et al*., 2013). Similar findings have been revealed by the present study. Moreover, in the present study % body fat was considerably better correlated with BMI (0.61*) than with BAI (0.36*). Many studies have stated limitation of BAI as an estimate of body fat (Lopez *et al*., 2012; Vinknes *et al*., 2013; Banik and Das, 2015). Our study also supports the findings of these previous studies. A body shape index (ABSI) showed decline in values from 10 to 14 years followed by an increase till 15 years showing lower values of waist circumference for height and weight of Bhil girls. All the circumferences among Bhil girls showed faster growth after 10 years with maximum gain between 10 and 11 years for upper arm circumference, 12 to 13 for waist circumference, 11to 12 for hip circumference and from 10 to 11 for calf circumference. Magnitude of gain also varied for different girths. This shows that girls gain fat mass as well as muscles throughout adolescence. Waist circumference alone is the most sensitive and reliable index to predict central obesity. Waist/hip ratio and waist height ratio are most commonly used indices for identifying overweight and obese adolescents and point towards developing metabolic complications in them. WC and WHtR are considered better predictors of central obesity than BMI by several researchers (Flegal *et al*., 2009; Hubert *et al*., 2009). Waist hip ratio among Bhil girls decreased from 0.81 at years to 0.75 at 16 years depicting greater deposition of fat in the hip region as compared to waist region. Similar findings have been reported by many previous researchers (Casey *et al*., 1994; Talwar *et al*., 2005; Talwar *et al*., 2010). Waist height ratio fluctuated between a very narrow range of 0.37 and 0.39 which is much below the cut off point (<0.5) reflecting linear physique. Subscapular and suprailiac skinfolds witnessed an increasing trend after 10 years till 16 years. Biceps and tricepsskinfold exhibited increasing trend till 12 years, followed by a fluctuating trend in biceps and decreasing trend in triceps till 15 years with maximum gain

between 15 and 16 years. Calf skin fold also increased regularly till 13 years followed by decrease till 15 years and rapidly increased thereafter. Many previous studies have shown that females show regular increases in sub scapular fat with increasing age but add relatively large amount of limbfat before the adolescent spurt. Centralization in girls occurs after the peak height velocity during late adolescence. There is a change in their fat pattern during puberty from a peripheral to centralized pattern (Baumgartner and Roche, 1988; Bjorntorp, 1996; Cameron, 1998; Talwar *et al*., 2001). It is also evident from the sub scapular/triceps ratio of Bhil girls which showed a decrease in the mean values from 0.97 at 9 years till 0.86 at 12 years showing greater deposition of extremity fat where after the values increased till 15 years showing greater trunkal fat. It clearly shows that the total fatness and hormonal environment play an important role in fat patterning. Our results are in consensus with the previous studies.

To study the variation in the body size, BMI of Bhil tribal girls has been compared with the BMI (Table 4) of Minas, Bhils, Sahariyas, Garasias, Damors and Kathodis tribals of Rajasthan studied by Bhasin and Jain in 2007. In all the tribal groups the mean values of BMI witnessed a general increase with the advancing age except minor fluctuations. Bhil girls of the present study showed greater mean values of BMI than the Bhil girls studied by Bhasin and Jain in 2007, which points towards some improvement in their nutritional status in the past eight years. Bhil girls of the present study when compared with other tribal groups showed greater BMI at 9 years than all the tribal populations but at 10 years Mina and Sahariya girls showed greater BMI than them. Sahariya, Garasia and Damor girls exhibited higher mean BMI than Bhil girls at 11 years. Sahariya and Garasia girls were ahead of them at 12 and Shariya girls were ahead of them at 13 years. However, at 14 years Bhil girls overtook all the tribal populations in their mean values. At 15 years, Mina and Sahariya girls possessed more BMI values than Bhil girls. At 16 years, Mina, Sahariya and Damor girls exhibited greater BMI values than Bhil girls. Bhil girls showed very low values of BMI at all (BMI less than 18) age groups pointing towards thinness and underweight. Similar findings have been reported by Bhasin and Jain (2007) among tribal populations including Bhils. Body Mass Index has been found to be positively correlated with socio-economic status and indicators of development (Shah *et al*., 1989 and Delpeuch *et al*., 1994). The present study reports similar findings.

Table 5 shows comparison of mean values of BMI of Bhil girls with BMI standards of WHO (2007) and BMI standards for Affluent Indians. BMI of Bhil girls when compared with BMI standards of WHO, 2007 and Affluent Indian Standards given by Aggarwal *et al* (2001); Khadilkar *et al* (2009) and Marwaha *et al* (2011) show considerably lower mean values of BMI at all ages.

The mean values of BMI of adolescent Bhil girls fell between 5th and 15th percentiles of WHO percentiles at age 9 years; between 1st and 3rd percentiles at age 10 and 11 years, at 3rd percentile at 12 years and reached 5th percentile at 13 years. At 14 years, the BMI values lied between 15th and 25th percentile, where after these fluctuated

between 5th and 15th percentiles till 16 years. These differences in their BMI with their western counterparts may be attributed to their genetic as well as environmental differences particularly to their poor socio-economic status, inadequate and poor nutrient intake and high energy expenditures, because these girls besides domestic work also worked in fields after school hours and during holidays. Height of Bhil girls when compared with WHO percentiles fell between 15th and 25th percentiles at 9 years where after it fell between 3rd and 5th percentile at 10 years; 5th and 15th percentile at 11 years; 3rd and 5th percentiles at 12 years and further fell between 1st and 3rd percentiles at 13 and 14 years to reach its lowest at 1st percentile at 15 years to bounce back between 3rd and 5th percentile at 16 years. It is evident from this comparison that Bhil girls exhibited stunted growth in height especially after the height spurt. WHO (1983) recommended cut-off point of –2 SD (< 3rd percentile) for malnourished children. As compared to affluent Indians also their BMI were considerably lower. Socio-economic differences along with synergistic action of nutritional deficiencies and infections have a direct bearing on body composition. Moreover, chronic under nutrition from early childhood continuing through adolescents is common among tribal populations. Similar findings have been reported by Bhasin and Jain (2007) among six tribal groups of Rajasthan including Bhil boys and girls.

CONCLUSIONS

Bhil girls experienced their height spurt between 10-11 years and peak weight gain was achieved between 13 and 14 years. Maximum gain in fat mass, fat free mass fat mass index and fat free mass index was also achieved between 13 to 14 years. Their fat free mass contributed more towards their BMI as compared to fat mass which is evident from the positive and highly significant values of FFMI with BMI. Waist hip ratio exhibited a decreasing trend showing more deposition of fat in the hip region as compared to waist. Subscapular/triceps ratio showed greater deposition of peripheral fat till 12 years followed by centralized fat pattern all through adolescence. Percent body fat was considerably better correlated with BMI than BAI in the present study showing BMI to be better predictor of fat than BAI. The study also shows that the fat distribution pattern among Bhil girls started emerging during puberty.

Table 1: Mean, Standard deviations (SD) and ANOVA of various anthropometric measurements in adolescent Bhil girls of District Udaipur.

Age (Years)	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*ANOVA*
Variables	*N=20*	*N=22*	*N=20*	*N=22*	*N=21*	*N=23*	*N=20*	*N=21*	*F value (p value)*
Stature (cm)									
Mean	127.71	127.77	135.91	138.71	141.74	144.89	145.53	150.58	26.23*
SD	8.31	8.28	7.55	7.94	8.51	6.93	6.72	4.24	0.00
Weight (kg)									
Mean	23.06	22.00	25.23	28.18	31.60	36.89	35.77	38.95	24.24*
SD	4.97	6.04	3.58	6.50	7.73	6.97	6.62	5.42	0.00
Circumferences (cm)									
Upper Arm									
Mean	16.06	15.74	17.17	17.39	18.56	19.39	19.41	20.63	15.19*
SD	1.42	1.80	2.10	18.56	2.34	2.11	2.13	2.32	0.00
Waist									
Mean	48.73	49.16	50.43	52.57	54.40	55.58	56.94	58.09	8.18*
SD	4.95	4.27	6.03	4.89	5.93	8.73	4.41	4.72	0.00
Hip									
Mean	59.95	60.31	63.73	68.23	69.11	70.77	71.90	77.56	16.54*
SD	5.43	7.83	8.31	6.58	7.93	6.80	5.88	5.18	0.000
Calf									
Mean	21.76	21.52	23.74	24.11	24.59	24.79	24.57	26.83	12.42*
SD	2.18	2.64	2.11	2.33	2.47	2.29	2.00	1.67	0.000
Skinfolds (mm)									
Biceps									
Mean	3.29	3.28	3.56	4.00	3.98	4.27	3.89	4.24	3.52*
SD	0.80	0.86	0.95	1.20	1.02	1.07	0.76	0.96	0.001
Triceps									
Mean	5.70	5.76	6.15	7.37	7.02	6.91	6.87	8.06	3.28*
SD	1.05	1.43	1.53	2.71	2.39	2.63	1.67	2.24	0.003
Subscapular									
Mean	5.45	5.12	5.77	6.16	7.17	6.80	7.37	8.19	4.86*
SD	0.92	1.22	1.34	2.70	3.50	1.31	2.51	2.61	0.000
Suprailiac									
Mean	4.97	4.67	5.32	5.99	6.72	6.54	6.96	7.40	5.54*
SD	0.95	1.19	1.50	1.96	2.65	1.69	2.36	2.66	0.000
Calf									
Mean	5.61	5.65	6.66	7.63	8.15	7.22	7.24	8.27	3.65*
SD	1.13	2.04	209	3.84	3.14	1.65	2.43	2.16	0.001
abbreviation "BiHB" (cm)									
Mean	5.03	4.95	5.07	5.17	5.42	5.50	5.59	5.56	5.64*
SD	0.52	0.68	0.43	0.47	0.42	0.56	0.41	0.45	0.000
abbreviation "BiFB" (cm)									
Mean	7.02	6.75	7.04	7.32	7.30	7.42	7.45	7.44	5.28*
SD	0.54	0.69	0.44	0.35	0.35	0.64	0.54	0.39	0.000

* significant at $p \leq 0.05$

BiHB=Bicondylar humerus breadth

BiFB=Bicondylar femur breadth

Table 2: Descriptive statistics of indices among adolescent Bhil girls of Udaipur

Age (Years) *Variables*	*9* *N=20*	*10* *N=22*	*11* *N=20*	*12* *N=22*	*13* *N=21*	*14* *N=23*	*15* *N=20*	*16* *N=21*	*ANOVA* *F value* *(p value)*
INDICES									
BMI (kg/m^2)									
Mean	14.04	13.26	13.71	14.57	15.51	17.59	16.78	17.17	10.83*
SD	2.17	2.29	1.86	2.62	2.37	3.22	2.19	2.26	0.00
GMT (mm)									
Mean	20.53	19.91	22.13	25.06	26.53	25.96	26.54	29.54	1.124
SD	3.28	4.59	4.80	8.69	9.43	5.74	7.20	7.61	0.351
Fat mass (kg)									
Mean	3.92	3.71	4.49	5.45	6.29	7.28	7.14	8.21	16.65*
SD	1.04	1.49	1.14	2.32	2.52	2.01	2.08	1.90	0.000
Fat free mass (kg)									
Mean	19.14	18.30	20.74	22.73	25.31	29.61	28.60	30.74	24.50*
SD	4.23	4.6	2.58	4.37	5.58	5.20	4.83	3.93	0.000
% Body Fat									
Mean	16.91	16.42	17.61	18.87	19.41	19.49	19.69	20.91	7.19*
SD	1.86	2.47	2.32	2.80	3.36	2.43	2.69	2.79	0.000
Waist Hip Ratio									
Mean	0.81	0.80	0.79	0.77	0.79	0.79	0.79	0.75	3.14*
SD	0.04	0.06	0.03	0.05	0.04	0.10	0.05	0.05	0.004
Subscapular to Triceps Ratio									
Mean	0.97	0.90	0.96	0.86	1.03	1.05	1.07	1.03	2.85*
SD	0.17	0.14	0.19	0.20	0.23	0.25	0.20	0.24	0.008
Fat Mass Index (kg/m^2)									
Mean	2.38	2.21	2.44	2.81	3.05	3.46	3.32	3.61	0.94
SD	0.49	0.68	0.60	1.04	0.93	0.88	0.75	0.80	0.48
Fat Free Mass Index (kg/m^2)									
Mean	11.66	11.05	11.27	11.76	12.46	14.13	13.45	13.56	9.23*
SD	1.76	1.68	1.34	1.68	1.70	2.47	1.65	1.67	0.000
Waist Height Ratio									
Mean	0.38	0.39	0.37	0.38	0.38	0.38	0.39	0.39	0.45
SD	0.04	0.03	0.04	0.03	0.03	0.06	0.02	0.03	0.87
ABSI									
Mean	0.75	0.78	0.76	0.75	0.74	0.69	0.73	0.71	3.67
SD	0.08	0.06	0.09	0.04	0.05	0.11	0.07	0.03	0.001
BAI									
Mean	23.68	23.72	22.25	23.79	22.90	22.67	22.99	24.00	0.65
SD	3.93	3.71	4.92	3.07	2.75	4.17	2.88	2.78	0.72

* significant at $p \leq 0.05$

Table 3: Age wise and Total Correlation of percent body fat, BMI, with various indices and ratios

Age Groups	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*Total*
N	*21*	*22*	*20*	*22*	*21*	*23*	*20*	*20*	*169*
Variables	*r(p value)*	*r(p value)*	*r (p value)*	*r(p value)*	*r(p value)*	*r (p value)*	*r(p value)*	*r(p value)*	*r(p value)*
%Body Fat									
BMI	0.19	0.69*	0.67*	0.82*	0.51*	0.40*	0.37	0.37	0.61*
	(0.205)	(0.000)	(0.001)	(0.000)	(0.009)	(0.029)	(0.054)	(0.054)	(0.000)
FMI	0.66*	0.10	0.92*	0.95*	0.90*	0.76*	0.85*	0.83*	-0.03
	(0.000)	(0.329)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.349)
FFMI	0.05	0.55*	0.52*	0.69*	0.21	0.25	0.11	0.10	0.44*
	(0.415)	(0.004)	(0.009)	(0.000)	(0.180)	(0.125)	(0.322)	(0.337)	(0.000)
WHR	0.16	-0.49*	-0.29	0.22	-0.19	-0.34	-0.21	-0.05	-0.29*
	(0.244)	(0.010)	(0.107)	(0.163)	(0.205)	(0.056)	(0.187)	(0.417)	(0.000)
WHtR	0.47*	0.09	0.51*	0.74*	0.51*	0.09	-0.26	0.23	0.31*
	(0.015)	(0.345)	(0.010)	(0.000)	(0.009)	(0.341)	(0.134)	(0.165)	(0.000)
Subscapular	0.06	0.18	-0.09	-0.07	0.24	-0.24	0.43	0.35	0.19*
triceps Ratio	(0.398)	(0.211)	(0.353)	(0.378)	(0.147)	(0.135)	(0.029)	(0.065)	(0.006)
GMT	0.99*	0.99*	0.99*	0.98*	0.97*	0.99*	0.98*	-0.19	0.03
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.211)	(0.349)
ABSI	0.27	-0.60	-0.04	-0.28	0.11	-0.24	-0.05	-0.21	-0.24*
	(0.118)	(0.001)	(0.433)	(0.103)	(0.317)	(0.135)	(0.417)	(0.187)	(0.001)
BAI	0.37*	0.35	0.59*	0.69*	0.44*	0.50*	0.19	0.29	0.36*
	(0.049)	(0.055)	(0.003)	(0.000)	(0.022)	(0.007)	(0.211)	(0.107)	(0.000)
BMI									
FM	0.77*	0.67*	0.77*	0.89*	0.81*	0.75*	0.75*	0.77*	0.83*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FFM	0.83*	0.87*	0.68*	0.81*	0.93*	0.85*	0.92*	0.89*	0.89*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FMI	0.86*	0.14	0.91*	0.94*	0.81*	0.89*	0.80*	0.82*	-0.02
	(0.000)	(0.267)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.398)
FFMI	0.99*	0.94*	0.98*	0.98*	0.95*	0.99*	0.96*	0.96*	0.98*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

* significant at $p \leq 0.05$

Table 4: Comparison of BMI of Adolescent Bhil Girls of Present Study With BMI of Adolescent Girls of six Tribal Groups of Rajasthan

Age	*Bhasin and Jain (2007)*						*Present study*
	Mina	*Bhils*	*Garasia*	*Sahariya*	*Damor*	*Kathodi*	*Bhils*
9	13.36	11.95	13.31	12.98	12.35	11.97	14.04
10	13.80	12.18	13.11	13.52	13.27	12.48	13.26
11	13.64	12.83	13.95	15.14	14.05	13.39	13.71
12	14.11	14.18	14.72	14.91	14.47	13.40	14.57
13	14.91	14.64	15.29	16.92	14.81	15.51	15.51
14	15.52	15.38	14.99	17.51	17.06	15.78	17.59
15	16.89	16.56	15.66	18.07	16.77	16.19	16.78
16	17.61	16.04	16.70	17.62	17.40	15.51	17.17

Table 5: Comparison of Mean Values of BMI of Adolescent Bhil Girls of Present Study with BMI of Affluent Girls

Age	*WHO (2007)*	*Agarwal et al (2001)*	*Khadilkar et al (2009)*	*Marwaha et al (2011)*	*Present study*
9	16.1	15.1	16.2	16.74	14.04
10	16.6	16.1	16.9	17.33	13.26
11	17.2	16.9	17.6	17.98	13.71
12	18.0	17.8	18.4	18.69	14.57
13	18.8	18.6	19.1	19.40	15.51
14	19.6	19.0	19.7	20.06	17.59
15	20.2	19.3	20.2	20.64	16.78
16	20.7	20.3	20.5	21.11	17.17

REFERENCES

Agarwal, K.N., Saxena, A., Bansal, A.K. and D.K. Agarwal., 2001. Physical Growth Assessment in Adolescence. *Indian Pediatr*., 38: 1217: 1235.

Banik, S. D. and S. Das., 2015. Body mass index and body adiposity index in relation to percent body fat: A study in adult men of three endogamous groups of South Bengal. *HOMO-Journal of Comparative Human Biology*., 66(1): 90-99.

Baumgartner, R.N. and A.F. Roche., 1988.Tracking of fat pattern indices in childhood: The Melbourne Growth Study. *Hum. Biol*., 60: 549-567.

Bergman, R. N., Stefanovski, D., Buchanan, T. A., Sumner, A. E., Reynolds, J. C., Sebring, N. G., ... and R.M. Watanabe., 2011. A better index of body adiposity. *Obesity*., 19(5): 1083-1089.

Bhasin, M.K. and S. Jain., 2007. Biology of the Tribal Groups of Rajasthan, India: 1. Body Mass Index as an Indicator of Nutritional Status. *Anthropologist*., 9(3): 165 175.

Bjçrntorp, P., 1996. The regulation of adipose tissue in humans. *Int. J. Obes. Relat. Metab. Discord*., 20: 219-302.

Cameron, N., 1998. Fat and fat patterning. In *The Cambridge Encyclopedia in human growth and development.* S.J. Ulijazek, F.E. Johnston and M.A. Preece (eds.). Cambridge University Press, Cambridge., 230-231.

Casey, V.A., Dwyer, J.H., Berkey, C.S., Bailey, S.M., Coleman, K.A. and I. Valadian.,1994. The distribution of body fat from childhood in a longitudinal study population. *Annal of Human Biology.,* 21: 39-55.

Daniels, S.R., Khoury,P.R. and J.A. Morrison., 2000.Utility of different measures of body fat distribution in children and adolescents.*American Journal of Epidemiology*., 152: 1179-1184.

Delpeuch, F., Cornu, A. and J.P. Massamba., 1994. Is body mass index sensitively related to socioeconomic status and economic adjustment? A case from the Congo. *Eur. J. Clin. Nutr.,* 48 (3): 14-147.

Durnin, J. V. G. A. and M. M. Rahaman., 1967. The assessment of the amount of fat in the human body from measurements of skinfold thickness. *British journal of Nutrition*., 21(3): 681-689.

El Aarbaoui, T., Samouda, H., Zitouni, D., Di Pompeo, C., De Beaufort, C., Trincaretto, F., ... and B.C. Guinhouya., 2013. Does the body adiposity index (BAI) apply to paediatric populations?. *Annals of human biology*., 40(5), 451-458.

Eveleth, P.B. and J.M. Tanner., 1990. Worldwide variation in human growth. Cambridge University Press, Cambridge., 222-240.

Fiori, G., Facchini, F., Pettener, D., Rimondi, A., Battistini, N. and G. Bedogni., 2000. Relationships between blood pressure, anthropometric characteristics and blood lipids in high-and low-altitude populations from Central Asia. *Annals of human biology*., *27*(1): 19-28.

Flegal, K.M., Shepherd, J.A., Looker A.C., Graubard, B.I., Borrud, L.G., Ogden. C.L., *et al.*, 2009. Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. *Am J Clin Nutr*., 89:500-508.

Gaur R. and J. Kaur., 2016. Physique and body composition of adolescent bhil boys of Udaipur area of Rajasthan. *Ind. J. Phys. Anthrop. & Hum.Genet*., 35(1): 23-36.

Good, C., Tulchinsky, M., Mauger, D., Demers, L. M. and R. S. Legro., 1999. Bone mineral density and body composition in lean women with polycystic ovary syndrome. *Fertility and sterility*., 72(1): 21-25.

Goon, D.T. and D. Tech., 2013. Fatness and fat patterning as independent anatomical characteristics of body composition: A study of Urban south African children. *Iran J. Pediatr.*, 23(4): 423-429.

Hubert, H., Guinhouya, C.B., Allard, L., and A. Durocher., 2009. Comparison of the diagnostic quality of body mass index, waist circumference and waist-to-height ratio in screening skinfold-determined obesity among children. *J Sci Med Sport*., 12: 449-451.

Indech, G.D., Sanjeev, J. and F.E. Johston., 1991. Age, Sex and Socio-economic correlates of fat patterning among adults from the Chandigarh zone of northwest India. *Ann. Hum. Biol.*, 18: 463-470.

Johnston, F. E., Hamill, P.V. and G. D. Indech., 1991.Fatness and fat patterning in 12-17 year old youth from the Chandigarh zone of Northwest India. *Am. J. Hum. Biol.*, 3: 587-597.

Kagawa, M., Byrne, N.M., King, N.A., Pal, S. and A.P. Hils., 2009. Ethnic differences inbody composition and anthropometric characteristics in Australian, Caucasion and urban indigenous children. *Br. J. Nutr*., 102: 928-946.

Khadgawat, R., Marwaha, R. K., Tandon, N., Mehan, N., Upadhyay, A. D., Sastry, A. and K. Bhadra., 2013. Percentage body fat in apparently healthy school children from northern India. *Indian pediatrics*., 50(9): 859-866.

Khadilkar, V.V., Khadilkar, A.V., Cole, T.J. and M.G. Sayyad., 2009. Cross-sectional Growth Curves for Height, Weight and Body Mass Index for Affluent Indian Children. *Indian Pediatrics*., 46: 477-489.

Krakauer, N. Y. and J. C. Krakauer., 2012. A new body shape index predicts mortality hazard independently of body mass index. *PloSone*., *7*(7): 39504.

López, A. A., Cespedes, M. L., Vicente, T., Tomas, M., Bennasar-Veny, M., Tauler, P. and A. Aguilo., 2012. Body adiposity index utilization in a Spanish Mediterranean population: comparison with the body mass index. *PloSone*., *7*(4): 35281.

Marwaha,R.K.,Tandon,N., Ganie, M.A., Kanwar, R., Shivaprasad, C., Sabharwal, A., Bhadra, K. and A. Narang., 2011. Nationwide reference data for height, weight and body mass index of Indian schoolchildren. *Natl Med J India.*, 24: 269–277.

Mukhopadhyay, A., Bhadra, M. and K. Bose., 2005. Regional Adiposity, Body Composition and Central Body Fat Distribution of 10–16 Years Old Bengalee Boys of Nimta, North 24 Parganas, West Bengal, India. *Coll. Antropol.,* 29(2): 487-492.

Norgan, N.G., 1998. Body Proportion Difference. *In: Cambridge Encyclopedia of Human Growth and Development*. S.J. Ulijaszek, F.E. Jihnston and M.A. Preece (Eds.). Cambridge University Press, Cambridge., 378-379.

Onis, M. D., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C. and J. Siekmann., 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World health Organization*., *85*(9): 660-667.

Rajkumari, B.,Akoijam, B. S., Akoijam, J. S.and U. Longjam., 2012. Assessment of body composition and body mass index of adolescent school children in Imphal-West district, Manipur. *J. Med Soc.,* 26:184-188.

Reddy, B. N., 1998. Body mass index and its association with socioeconomic and behavioural variables among socioeconomically heterogeneous populations of Andhra Pradesh, India. *Human Biology*., 901-917.

Rolland-Cachera, M. F., 1993. Body composition during adolescence: methods, limitations and determinants. *Hormone Research in Paediatrics*., 39(3): 25-40.

Rosa, M.L.G., Mesquita, E. T., Rocha, E. R. R. and V. M. Fonseca., 2007. Body mass index and waist circumference as markers of arterial hypertensionin adolescents. *Arq.Bras. Cardiol.*, 88:573-578.

Shah, M., Jeffrey, R.W., Hannan, P.J. and L. Honstad., 1989. Relationship between sociodemographic and behavior variables and body mass index in a population with high normal blood pressure: Hypertension prevention trial. *Eur. J. Clin. Nutr*., 43: 583-596.

Sharma, V. K., Subramanian, S. K. and V. Arunachalam., 2013. Evaluation of body composition and its association with cardio respiratory fitness in south Indian adolescents. Indian Journal of Physiology and Pharmacology., 57(4): 399-405.

Sinha, R. and S. Kapoor., 2005.Fat patterning among Indian adolescent boys and girls. *Indian J Phys Anthropol Hum Genet.,* 24: 135–141.

Siri, W. E., 1956. The gross composition of the body. *AdvBiol Med Phys*., *4*(239-279): 513.

Talwar, I., Gurpreet and Balpinder.,2001. Fatness and fat patterning among Jat adolescent females. The science of man in service of man. Bhasin M.K., Malik S.L. (eds.) Department of Anthropology, University of Delhi., 103-111.

Talwar. I., Vasudha. andP. Bajwa., 2005. Fatness and Regional Distribution of Body Fat among Adolescent Brahmin Girls. *Indian J. Phys Anthrop Hum. Genet.,* 24: 143–151.

Talwar, I., Sharma, K. and S. Kapur., 2010. Growth Trends in Body, Fat, Circumferential and Physiological traits during Adolescence among Rajput Females of Theog, Shimla District (Himachal Pradesh). *Annals of Human Biology*., 37(4): 536-553.

Talwar, I., Kaur, B. and V. Negi., 2011. Growth trends in bodily dimensions and fat distribution pattern during adolescence among Rajput boys of Kullu valley. *Indian Journal of Anthropology and Human Genetics*., 30: 183-200.

Tanner, J. M., 1962. Growth at adolescence.2nd ed. Thomas: Springfield, Ill.

Tanner, J. M., Whitehouse, R. H., and M. Takaishi., 1966. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I. *Archives of Disease in Childhood*., *41*(219): 454.

VanItallie, T. B., Yang, M. U., Heymsfield, S. B., Funk, R. C. and R. A. Boileau., 1990. Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. *The American journal of clinical nutrition*., *52*(6): 953-959.

Vinknes, K.J., Elshorbagy, A.K., Drevon, C.A., Gjesdal, C.G., Tell,G.S., Nygård, O., Vollset, S.E. and H. Refsum., 2013. Evaluation of the body adiposity index in a Caucasian population, The Hordaland Health Study. *Am. J. Epidemiol*., 177: 586–592.

Weiner, J. S. and J. A. Lourie., 1969. Human Biology, A Guide to Field Methods.

Wells, J.C. K. 2001. A critique of the expression of paediatric body composition data. *Arch Dis Child*., 85: 67-72.

Wells, J. C. K. and M. S. Fewtrell, 2006. Measuring body composition. *Archives of disease in childhood*., 91(7): 612-617.

World Health Organization,1983. Measuring change in nutritional status: guidelines for assessing the nutritional impact of supplementary feeding programmes for vulnerable groups, Geneva.