SEGMENTAL BIOELECTRICAL IMPEDANCE ANALYSIS IN CHILDREN AGED 7–18 YEARS LIVING IN ANKARA-TURKEY: AGE AND SEX DIFFERENCE IN THE MEASURES OF ADIPOSITY

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ABSTRACT

Background: Obesity among school children has emerged considerably in the recent years with changing of life styles.

Aim: The present study analyses the patterns of fat accumulation during childhood and adolescents.

Subjects and methods: A Cross-sectional sample of 684 female and 687 male (total 1,371) Turkish children, aged 7–18 years, were selected randomly from schools, by the permission of the Turkish National Educational Ministry. The percentage of bodyfat (BF), the weight of fat mass (FM) and the fat free mass (FFM) in trunk, right and left leg, right and left arm (all in kg) were estimated.

Results: The findings revealed a significant increase in BMI, BF, FFM, the trunk fat and the trunk muscle mass over the studied age periods in both sexes. The mean trunk FFM and trunk FM were higher in males than in the females. On the contrary, the mean trunk FM and whole body FM for females were higher than in males. During the years of adolescence FFM, as well as BF, increases in the males and the gains are considerably greater than noticed in the females, who accumulate more body fat.

Conclusion: The present study generates the baseline data for undertaking future investigations on the obesity of the Turkish children.

Keywords: *obesity, bioelectrical impedance, body segments, fat pattern, Turkish children*

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INTRODUCTION

The data on the composition of individual body segments generate greater understanding of growth and development, the process which, on the other hand, is affecetd due to exercise, disease or trauma [14]. The assessment of body fat in children provides important information in the diagnosis and the treatment of childhood obesity. Various techniques are available to estimate body composition and fat distribution, such as underwater weighing, dilution techniques and dual-energy X-ray absorptiometry (DXA) are all reliable methods to obtain accurate measures of total body fat. However, because of their costs in terms of time and money, these methods are not practically useful in largescale epidemiological studies and for routine clinical use. In such situations, the body mass index (BMI) is often used and assumed to represent indirectly the degree of body fat. But BMI does not differantiate between the fat mass and the lean mass (non-fat) [7, 19]. The bio-electrical impedance analysis (BIA), through the use of polar electrodes provides information on body fat, trunk fat, leg and arm fat for both sides of the extremities with an easy and fast procedure.

It has been observed that overweight children tend to grow up into adulthood as overweight individuals. Therefore they have a higher risk of developing hazardous health problems in later life, including heart attack and stroke, type-II diabetes, bowel cancer, high blood pressure, etc.[8, 33]. Most children put on excess weight because of their lifestyles including an unhealthy diet and the lack of physical activity [9].

It is now well known that, in addition to total body fat, excessive fat distribution is a major risk factor for various diseases in adults [32] and children like cardiovascular diseases and insulin resistance/diabetes [5, 7, 43, 21, 41, 11, 12, 39]. Thus with rapid increase of prevalance obesity among the children, it is important to examine the nature of fat distribution in the life period and when gender differences in fat patterning emerge.

A number of authors have previously described the relationship between age, sex and subcutaneous fat distribution in childhood and adolescence [26, 4, 20]. Some have stated that sexual dimorphism in fat patterning appears at puberty [24, 6, 18].

A tendency towards truncal/central fat distribution in children of prepubertal ages has been reported in the German [28], USA [1] and the Spanish population [30]. Since fat distribution plays a major role in both morbidity and mortality, it is important to examine the nature and timing of fat patterning in children. The aim of this paper is to evaluate the effects of age and sex on relative fat distribution, particularly on central (trunk) and extremity (perifeal) fatness, during childhood and adolescence in urban school children from Ankara, the capital of Turkey.

MATERIAL AND METHODS

The study has been performed on a cross-sectional sample of 684 female and 687 male (total 1,371) Turkish children aged 7–18 years (Table 1) obtained from the primary and secondary urban schools in Ankara, the capital city of Turkey. The sample has been randomly choosen both from public and private schools for soscio-economic structure representative purposes, and the study conducted under the permission of the Turkish National Educational Ministry and local area boards. The decimal age for each individual was computed as the difference between the date of measurement and the date of birth.

Table 1. Number of children and adolescents according to the age and sex groups

Age group	Boys	Girls	Total
7	35	41	76
8	77	69	146
9	67	51	118
10	81	78	159
11	71	68	139
12	36	69	105
13	63	53	116
14	68	74	142
15	52	58	110
16	60	47	107
17	50	56	106
18	27	20	47
Total	687	684	1371

Measurements were performed by four experienced measurers. All the measurements were taken from the children with minimum indoor clothing and bare feet. Anthropometric variables (height, weight) were measured according to the standard anthropometric protocols [23]. The stature was measured to the nearest millimetre with a Martin type anthropometer. The individuals were asked to remove their shoes, jewellery, and hair clips. Weight was measured without shoes and with light cloths to the nearest 0.1 kg, using an electronic scale (Tanita BC-418TM). The body mass index (BMI) (kg/m^2) was derived from these two measures. Body fatness was estimated by the bio-electrical impedance analysis method, by the use of 8 polar electrodes (Tanita Bioimpedence Model BC-418TM). The segmental body composition analyzer shows separate body mass readings for body fat (BF), trunk fat (TF), fat free mass (FFM), right and left leg fat (kg), right and left arm fat (kg). Participants stood barefoot on a platform with electrodes. Verbal consent was ascertained from each child and written informed consent obtained from the Turkish Ministry of Education.

Statistical analysis

Descriptive statistics of all the variables stated earlier, were made according to age and sex. The data were grouped by age and sex by single year groups. Age refers to the midpoints of the intervals, e.g., 7 years refers to the data from children ranging in age from 6.50 to 7.49 years. The Pearson correlations between these measures were calculated (P<0,01; P<0,05). The results were compared within and between age groups using paired and unpaired Student's t –tests (P<0,01; P<0,05). Variation by sex and age was tested using ANOVA (P<0,01; P<0,05). Data were analysed using SPSS 13.0 version.

RESULTS

Tables 2 and 3 show the means and standard deviations by age and sex, as well as the results of the univariate analysis of variance. Table 4 presents the correlation matrix between these measurements. In the tables, the age groups were splited into three subgroups. The first group started from 6.5 to 10.49 year, the second group started from 10.5 to 13.49 year and the last group started from 13.5 to 18.49 years.

The results show that older children have a more central pattern of fat distribution than younger children. Moreover, boys have consistently more central fat than girls at older ages (Fig. 1) (P<0.05). However, trunk fat starts decreasing in 14 years which suggests that even at this young age there is a clear evidence of sexual dimorphism in fat patterning, with girls showing greater subcutaneous adiposity mainly contributed by legs and trunk.

There was a positive and significant association, as determined by the Spearman rank correlation coefficient, between age and other anthropometric measurements in both males ($r \geq 0.508$) and females ($r \geq 0.259$) except for trunk fat and body fat (%) in boys. At all ages, the mean body fat (%), left leg fat (kg), right arm fat (kg), trunk body fat values was higher in girls than in boys. There was a negative correlation between age and body fat (%) in boys but there is no corelation between trunk body fat (%) and age. Using correlation coeficients, BMI, weight, and the body fat percentage were found to be statistically signignificant within all the anthropometric measurements ($p < 0.01$). This indicates that BMI can still be used to determine obesity status in this population.

Table 2. Mean, standard deviation and the univariate analysis of variance by age for boys

	6.5–10.49 yrs		10.5–13.49 yrs		13.5–18.49 yrs		p	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Age**	**Sex**
Stature (cm)	131.10	101.67	146.52	11.18	169.66	9.67	***	**
Weight (kg)	30.23	8.714	40.98	12.73	64.74	14.61	***	***
BMI (kg/m^2)	17.43	2.90	18.80	3.76	22.36	4.06	***	ns
Body Fat (%)	19.81	5.67	19.21	6.63	18.68	6.33	ns	***
Bod Fat (kg)	6.27	3.51	8.44	6.07	12.79	6.93	***	***
Fat Free Mass (kg)	23.98	6.03	32.52	7.93	52.03	9.40	***	***
Right Leg Fat (kg)	1.44	0.91	3.65	23.22	2.73	1.44	ns	ns
Right Leg FFM (kg)	3.82	1.50	5.55	1.80	9.28	1.83	***	***
Left Leg Fat (kg)	1.37	0.75	1.85	1.50	2.76	1.47	***	***
Left Leg FFM (kg)	3.65	1.31	5.33	1.72	8.97	1.80	***	***
Right Arm Fat (kg)	0.39	0.19	0.58	0.34	0.83	0.54	***	**
Right Arm FFM (kg)	0.96	0.35	1.45	0.45	2.60	0.61	***	***
Left Arm Fat (kg)	0.43	0.22	0.62	0.41	0.89	0.40	***	**
Left Arm FFM (kg)	1.01	0.34	1.49	0.46	2.61	0.53	***	***
Trunk Body Fat (kg)	2.70	1.78	3.64	2.62	5.60	3.46	***	***
Trunk Body Fat (%)	14.87	6.27	15.18	6.99	15.53	7.36	ns	***

** $p< 0.05$; *** $p< 0.001$; ns, not significant

Table 3. Mean, standard deviation and the univariate analysis of variance by age for girls

	6.5–10.49 yrs		10.5–13.49 yrs		13.5–18.49 yrs		p	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Age**	**Sex**
Stature (cm)	129.93	9.38	149.72	8.02	159.23	5.94	***	**
Weight (kg)	29.44	8.51	43.35	9.87	54.87	9.21	***	***
BMI (kg/m^2)	17.23	3.03	19.39	3.22	21.76	3.36	***	ns
Body Fat (%)	22.96	5.16	24.25	4.83	26.06	5.72	***	***
Bod Fat (kg)	7.09	3.82	10.99	4.57	14.73	5.48	***	***
Fat Free Mass (kg)	22.36	5.07	32.48	5.93	40.31	4.52	***	***
Right Leg Fat (kg)	1,61	0.77	2.58	0.94	3.41	1.01	***	ns
Right Leg FFM (kg)	3.59	1.98	5.26	1.16	6.72	0.95	***	***
Left Leg Fat (kg)	1.60	0.76	2.52	0.92	3.31	1.01	***	***
Left Leg FFM (kg)	3.36	0.88	5.09	1.09	6.58	0.91	***	***
Right Arm Fat (kg)	0.44	0.21	0.69	0.42	0.80	0.32	***	**
Right Arm FFM (kg)	0.86	0.26	1.35	0.39	1.78	0.29	***	***
Left Arm Fat (kg)	0.49	0.28	0.76	0.31	0.91	0.43	***	**
Left Arm FFM (kg)	0.89	0.26	1.37	0.30	1.80	0.29	***	***
Trunk Body Fat (kg)	2.98	1.84	4.47	2.14	6.40	3.08	***	***
Trunk Body Fat (%)	16.75	5.81	17.83	5.57	20.56	6.95	***	***

** $p< 0.05$; *** $p< 0.001$; ns, not significant

Table 4. Variations by age and sex by the Spearman rank correlation

	Girls	Boys
Stature (cm)	0.863**	0.869**
Weight (kg)	0.808**	0.825**
BMI (kg/m^2)	0.574**	0.564**
Body Fat (%)	0.259**	–0.160**
Bod Fat (kg)	0.644**	0.565**
Fat Free Mass (kg)	0.868**	0.872**
Right Leg Fat (kg)	0.714**	0.533**
Right Leg FFM (kg)	0.848**	0.836**
Left Leg Fat (kg)	0.698**	0.556**
Left Leg FFM (kg)	0.878**	0.836**
Right Arm Fat (kg)	0.555**	0.672**
Right Arm FFM (kg)	0.869**	0.874**
Left Arm Fat (kg)	0.523**	0.646**
Left Arm FFM (kg)	0.857**	0.870**
Trunk Body Fat (kg)	0.271**	0.008
Trunk Body Fat (%)	0.573**	0.508**

** Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level.

Figure 1 shows the relationship between the percentage of total body fat and BMI in males and females. A positive correlation between the parameters was found in both male and females. Female subjects showed a very high correlation ($p<0.01$) and steeper inclination of the regression line than the male subjects ($p<0.01$).

Body fat depositions in central vs peripheral and upper vs lower body locations were examined by sex. Figure 2 shows the distribution of total body fat and trunk fat by age groups. The total body fat decreases gradually through ages for boys. In girls there is a prominent peak around age 14 and then the rapid decline until age 18.

Figure 3 represents the distribution of the extremity fat through ages for both sexes. Both the left and right leg fat tendency was found to be similar in boys and girls although, the arm fat distribution differs in boys with having greater values. The right and the left arm fat shows disparities in both sexes. In contrast, there were no differences between the left and the right leg fatness.

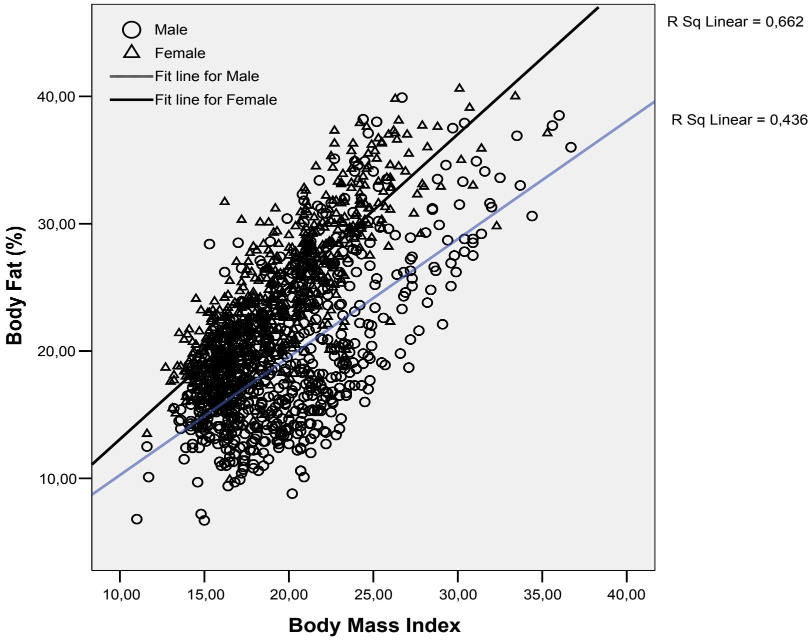

Figure 1. Relation between the total body fat (kg) and the body mass index for males and females.

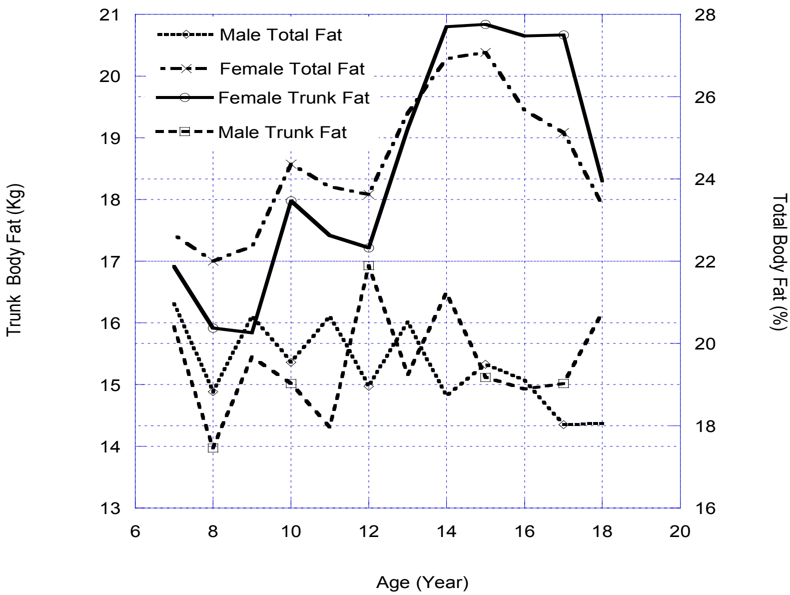

Figure 2. Distribution of the total body fat and the trunk fat by age and sexes.

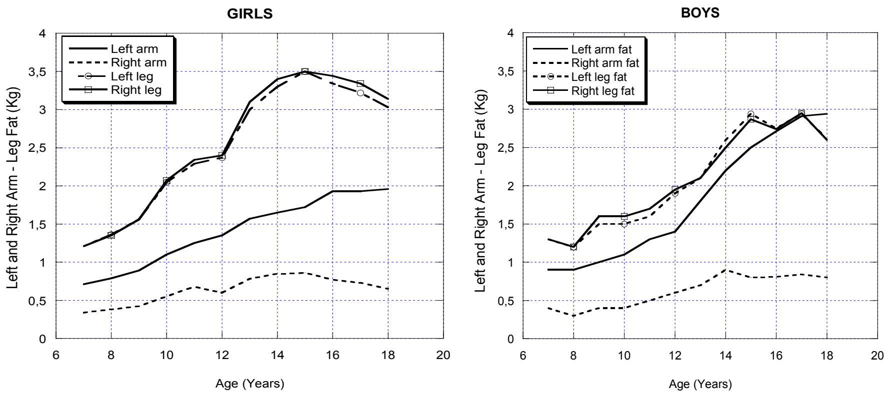

Figure 3. Distribution of extremity fatness by age and sexes.

DISCUSSION

In the present study, BIA was used to investigate the fat distribution because this method enabled us to measure the total body fat and its regional distribution. Girls had more body fat with a larger trunk and lower extremity fat, and a larger proportion of peripheral vs central fat than boys. Some of the contrasts between the sexes that were observed in this study have been found in some other studies of the population such as African-American, Asian, Caucasian [16] and European children [44, 42, 35]. In the present study the total fat ratio correlated positively with BMI in both sexes. The female subjects showed a higher correlation coefficient and steeper inclination value of the regression line than the males. These findings indicated that the female body fat accumulation is greater than the male deposition. It is likely that a given increase in BMI reflects more severely the fat deposition in females than in males. These explanations may answer a query as to why female subjects showed greater total body fat than male subjects in the present study.

The present study demostrated the degree of total body fat and its regional distribution to the lower segment of the body were greater in females than in male. It has been presented that males the administration of testosterone reduces the visceral fat deposition but not the subcutaneous fat deposition, consequently changing the ratio of visceral and subcutaneaous adipose tissues [27]. The abdominal fat that contributes mainly to the fat deposition at the upper body segment possesses a high activites of both lipogeesis and lipolysis [29]. These characteristics of lipid metabolism in visceral and subcutaneous adipose tissues may cause differences in the development of several metabolic disorders [34].

The finding of greater whole-body fat in the girls of this study than in the boys was confirmed for each individual segment. Sex differences in the body fat increased at 7 years and showed a peak at 14 years. Studies reflect that sexual dimorphism in fat patterning has been regarded as occurring at puberty [42]. The body fat depositions in central vs peripheral and upper vs lower body locations were examined by sexes. The body fat distribution to central vs peripheral depots may differ by sex. Findings from the Bogalusa Heart Study have shown that increased central body fat in children is related to adverse changes in lipid profiles [12], insulin metabolism [11] and blood pressure [39]. More recently, these workers [10] have emphasised the importance of measuring fat distribution in children as a method of identifying those at risk from obesity and associated morbidity. The present study confirms the findings of American [1] and European [28, 30] researchers that sexual dimorphism of fat patterning in children is present at 5–7 years of age. Our study shows that increased central body fat in girls but former study show that increased central body fat in children is related to adverse changes in lipid profiles [12], insulin metabolism [11] and blood pressure [39]. We found that body fat distribution is dependent on age.

Height is more strongly related to indicators of lean body mass than to the indicator of adiposity [25, 37]. A child with a greater muscle size would reflect a greater protein reserve [13]. The lowest musculature is related to the lowest height [2].

Epidemiological and experimental studies indicate that protein reserves are utilized only after the calorie reserves in the form of body fat are depleted [40, 38]. Similarly, growth retardation in height occurs in general terms, under the condition of cronoic undernutriton [22,15]. Genetic factors, life style, illness may also influence anthropometric measurements. The children tend to be fatty and overweight, while their muscule mass and height are proportionally low.

The greater increase of the central body fat after puberty (Table 2) contributes to the observed increase of the first factor scores after 15 years in boys and 13 years in girls. At the end of the growth period, centralization becomes higher in boys than in girls because boys acquire proportionately more subcutaneous fat on the trunk than on the extremities compared to females. The observed trend to greater central subcutaneous fatness with age can be interpreted as a redistribution effect of subcutaneous fat from the extremities to the trunk during adolescence [31, 3, 26, 36]. The increase in fat centralization can be considered a masculinizing and hormonally induced process [31] since it can be clearly noted in boys but not in girls.

CONCLUSION

The results of this study in children of 7–18 years of age, comparing segmental BIA with segment composition, suggest the following: trunk fatness shows the greatest variability between individuals. The present study confirms that sexual dimorphism of fat patterning in children is present at 7–18 years of age. To prevent further increases of body fatness, the population-level strategies must be applied and the population specific new longitudinal studies are needed for a better estimation of the obesity and body fat status children and adolescents.

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