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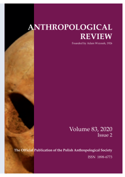

Evaluation of upper arm muscle and fat area of children and adolescents from Ankara, Turkey

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ABSTRACT: Arm anthropometry is a commonly used method for determining the nutritional status of children and adolescents. The purpose of the study is to evaluate the arm anthropometry of 1484 children and adolescents (760 boys and 724 girls) aged between 6–17 years. The sample groups are selected who are living in Ankara to establish local reference values. In order to determine upper Arm Muscle Area (AMA) and upper Arm Fat Area (AFA), height, weight, upper arm circumference and triceps skinfold thickness measurements were taken in accordance with International Biological Program (IBP) protocols. Smoothed percentiles of AMA and AFA were obtained. Body mass index was calculated with weight and height measurements (kg/m^2). Fat mass (FM) and fat free mass (FFM) were measured using bio-impedance analyzer. According to the obtained results, arm muscle area values were higher in boys and arm fat area was higher in girls. In addition, sex difference in these variables increased with age. There was a high positive correlation between body mass index (BMI) and AMA, AFA. It has been found that there is a difference in AMA and AFA values for Ankara children compared to previous studies in Turkey.

KEY WORDS: Nutritional status, Arm muscle area, Arm fat area, Turkey

Introduction

Obesity is a serious health problem that affects both adulthood, as well as growth and development period. It is associated with many short and long-term adverse health consequences (Must and Strauss 1999; Reilly et al. 2003) and obesity in childhood is likely to continue in adulthood (Herman et al. 2009). Overweight and obesity rates have increased significantly in children and adolescents worldwide, especially in the past 40 years (WHO 2019a). It is stated that this increment more rapid in low and middle-income countries (WHO 2016; Lobstein et al. 2015). According to previous studies the increase in the rate of overweight and obesity has been demonstrated in Turkey (Alper et al. 2018). On the other hand, malnutrition threatens the lives of children, especially in developing countries. According to data from the World Health Organization (WHO), almost half

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of child mortalities under 5 are caused by malnutrition across the world (WHO 2019b). Similar to the global trend, a serious decline in stunting rates in the years 2008–2018 was observed in Turkish children under 5 years. It has been reported that there has been no change in underweight rates, which is one of the indicator of protein energy malnutrition during the last 10 years (Hacettepe University Institute of Population Studies 2019).

Arm anthropometry is a commonly used method for determining the nutritional status of children and adolescents. The upper arm muscle area gives information about the organic protein pool that is related with the linear correlation between the body muscle mass and the organic protein pool, while the upper arm fat area is an indicator of the calorie reserve (Frisancho 1974; Frisancho 1981; Bolzan et al.1999; Rolland Cachera 1993; Heymsfield et al. 1982). In addition, when these variables are considered at the population level, there is a correlation with the whole body fatness and muscularity (Zemel 2002). On the other hand, the upper arm muscle area is linearly associated with total body muscle and is a good indicator of protein malnutrition (Heymsfield et al. 1982). It is proposed to use the upper arm muscle area and arm fat area method instead of using the skinfold thickness and upper arm circumference directly (Frisancho 1981). Although there have been studies that have evaluated the nutritional status using the arm anthropometry for the last decades, the studies on the use of arm muscle area and arm fat area in Turkish children are limited (Derman 2002; Gültekin et al. 2006; Öztürk et al. 2009; Çiçek et al. 2014). The aim of this research is to evaluate the arm anthropometry of children and adolescents aged 6–17 in Ankara, and to show the changes in the arm muscle and fat areas of Turkish children compared to other research conducted in Turkey during about last decade. Upper arm muscle area and fat area values are expected to be significantly different between sexes and ages in this research. The data obtained as a result of this research are expected to show that the nutritional status of children and adolescents has significantly changed in comparison with comparing with previous research in Turkey.

Material and methods

The sample of this cross-sectional study was composed of 1484 healthy children and adolescents (760 boys and 724 girls) between the ages of 6–17 in Ankara (Turkey) from different socioeconomic background. Children and adolescents studying from primary, secondary and high schools in public schools in Ankara were included in the research. The research was carried out during the academic year of 2016–2017 after obtaining the required permissions from the ethics committee of the Ankara University and The National Education Directorate. On the other hand, permission was taken from each child and their parents considering volunteering.

Anthropometric measurements

Height, weight, triceps skinfold thickness (TS), and Mid-Upper Arm Circumference (MUAC) were taken in accordance with the International Biological Program protocol (Weiner and Lourie 1969). Height was measured with a Seca 213 stadiometer and weight, FM (fat mass) FFM (fat free mass) was measured with the TANITA SC330S body analyzer. The circumference of the mid-upper arm was measured by a tape meter and the triceps skinfold thickness was measured by Holtain skinfold caliper. Body mass index was calculated with weight and height measurements (kg/m^2).

Arm anthropometry

The AMA and AFA equations were exploited using anthropometric measurements of upper arm circumference and triceps skinfold thickness to determine upper arm muscle and fat area (Frisancho 1974) (1,2):

$$AMA\ (cm^2) = [c - (\pi \times TS)]^2 / 4 \times \pi \quad (1)$$

$$AFA\ (cm^2) = (c^2 / 4 \times \pi) - AMA \quad (2)$$

where: c – upper arm circumferences, TS – triceps skinfold.

Statistical analysis

SPSS 20 version was used in the statistical evaluation of the data, parametric or nonparametric tests were applied according to whether they were distributed normally or not. Mann Whitney U and independent t test were used to determine the difference between the means, Spearman correlation analysis was used to determine the relationship between variables. The smoothed percentiles of the measurements were obtained by the LMS program, and the 3th, 5th, 10th, 25th, 50th, 75th, 90th, 95th, 97th percentiles were determined. With the LMS method, a distribution is obtained by taking into account the degree of skewness (L-lambda), the central tendency (M-median) and the coefficient of variation (S-sigma) (Cole & Green 1992). Smoothed percentiles plotted with Kaleidagraph 3.5.

Results

BMI, MUAC, TS, AMA, AFA, FM and FFM mean values in children and adolescents were presented in Table 1 and 2. BMI, MUAC and AMA mean values increased with age in both sexes. According to the results of this research, mean values of triceps skinfold decreased in boys from 11 to 16 years of age, while AFA values also decreased from 13 to 16 years of age. Triceps skinfold and AFA mean values decreased in 11–12 years old girls. Especially with the beginning of the adolescence period, the difference between sexes was observed to be increasing. In general, except BMI, it is possible to say that all variables were significantly different between sexes after the age of 15 years ($p<0.05$, $p<0.001$).

There was a significant positive correlation between BMI values and AMA (r_s: 0.749 for boys, r_s: 0.786 for girls) BMI and AFA (r_s: 0.780 for boys, r_s: 0.841 for girls) at $p<0.001$ level. A high positive correlation was found between FFM and BMI in both sexes (r_s: 0.708 for boys, r_s: 0.759 for girls) ($p<0.001$). The significant very high positive correlation was found between AFA and TS in girls (r_s:0.956), AMA and MUAC in boys (r_s:0.932) ($p<0.001$). The correlation between FM and AFA was found to be higher in girls (r_s:0.853) and between AMA and FFM higher in boys (r_s:0.903) ($p<0.001$) (Table 3).

In Figure 1–4, selected smoothed percentiles of MUAC, TS, AMA and AFA in selected ages were presented. In general, comparing both sexes, 50th percentile of AMA had higher values in boys and AFA was higher in girls.

Table 1. MUAC, TS, AMA and AFA mean and standard deviation (SD) by age and sex

	MUAC (cm)			TS (mm)			AMA cm²			AFA cm²		
Boys												
Age	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*
6	76	17.95 (2.10)	0.986	76	10.43 (3.78)	0.011	76	17.28 (3.21)	0.059	76	8.71 (3.91)	0.044
7	71	18.58 (3.03)	0.459	71	11.08 (4.52)	0.977	71	18.51 (6.00)	0.388	71	9.69 (5.68)	0.714
8	71	19.43 (3.09)	0.910	72	12.11 (4.92)	0.238	71	19.71 (5.08)	0.507	71	11.09 (5.92)	0.573
9	82	20.43 (2.86)	0.723	82	13.06 (4.98)	0.694	82	21.48 (4.75)	0.529	82	12.39 (5.88)	0.813
10	79	21.45 (3.58)	0.247	79	13.54 (5.96)	0.698	79	23.94 (6.44)	0.057	79	13.69 (7.81)	0.906
11	67	22.79 (3.57)	0.041	67	14.23 (5.91)	0.719	67	27.19 (7.27)	0.016	67	15.17 (7.78)	0.379
12	71	23.70 (3.65)	0.188	71	14.19 (5.86)	0.405	71	30.02 (8.61)	0.331	71	15.73 (8.25)	0.281
13	41	23.71 (3.74)	0.955	41	13.94 (6.49)	0.247	41	30.23 (7.67)	0.545	41	15.60 (9.15)	0.249
14	36	24.90 (3.56)	0.305	36	12.43 (6.00)	0.003	36	35.68 (9.72)	0.002	36	14.65 (8.18)	0.023
15	57	26.45 (3.46)	<0.001	57	11.28 (6.85)	<0.001	57	42.22 (8.48)	<0.001	57	14.43 (10.25)	<0.001
16	77	25.94 (2.83)	<0.001	78	8.99 (3.78)	<0.001	77	43.02 (9.58)	<0.001	77	11.17 (5.10)	<0.001
17	31	27.16 (3.86)	0.023	31	9.79 (5.34)	<0.001	31	46.88 (11.61)	<0.001	31	12.99 (9.28)	<0.001
Girls												
Age	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*
6	70	18.00 (2.66)	0.986	70	11.77 (3.51)	0.011	70	16.66 (5.75)	0.059	70	9.68 (3.87)	0.044
7	58	18.01 (2.74)	0.459	58	10.66 (3.34)	0.977	58	17.54 (6.05)	0.388	58	8.86 (3.57)	0.714
8	50	19.31 (3.05)	0.910	50	12.70 (4.23)	0.238	50	19.14 (5.73)	0.507	50	11.26 (5.11)	0.573
9	51	20.55 (3.54)	0.723	51	13.31 (4.91)	0.694	51	21.85 (7.69)	0.529	51	12.74 (6.63)	0.813
10	49	20.75 (3.51)	0.247	49	13.94 (5.87)	0.698	49	21.73 (6.22)	0.057	49	13.51 (7.48)	0.906
11	69	21.38 (2.70)	0.041	69	13.43 (4.40)	0.719	69	23.79 (5.68)	0.016	69	13.16 (5.28)	0.379
12	53	22.88 (2.98)	0.188	53	13.38 (4.55)	0.405	53	28.12 (6.30)	0.331	53	14.27 (6.13)	0.281
13	40	23.91 (3.49)	0.955	40	15.07 (4.90)	0.247	40	29.71 (7.75)	0.545	40	16.74 (7.86)	0.249
14	60	24.22 (2.86)	0.305	60	15.84 (4.88)	0.003	60	29.86 (7.17)	0.002	60	17.46 (6.58)	0.023
15	106	24.06 (2.83)	<0.001	107	16.08 (5.17)	<0.001	106	29.12 (6.81)	<0.001	106	17.61 (7.05)	<0.001
16	86	24.37 (3.05)	<0.001	86	16.46 (4.38)	<0.001	86	29.85 (8.26)	<0.001	86	18.16 (6.19)	<0.001
17	30	24.90 (3.71)	0.023	30	17.11 (5.32)	<0.001	30	31.02 (10.23)	<0.001	30	19.39 (7.88)	<0.001

Table 2. BMI, FM and FFM mean and standard deviation (SD) by age and sex

	BMI			FM			FFM		
				Boys					
Age	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*
6	76	16.74 (2.38)	0.445	37	4.72 (1.92)	0.547	36	18.63 (2.51)	0.004*
7	71	17.06 (3.36)	0.150	64	5.35 (4.54)	0.813	64	20.53 (3.47)	0.053
8	72	17.65 (3.69)	0.779	69	6.18 (3.98)	0.062	66	23.65 (4.89)	0.036*
9	80	18.72 (3.48)	0.066	75	7.75 (4.61)	0.848	68	27.19 (6.08)	0.018*
10	79	18.68 (4.07)	0.248	76	8.45 (6.00)	0.765	59	29.89 (5.87)	0.006*
11	67	20.45 (4.22)	0.036*	66	9.60 (6.05)	0.472	54	35.19 (7.91)	<0.001**
12	71	20.64 (4.28)	0.341	70	9.62 (6.72)	0.044*	64	39.86 (7.69)	<0.001**
13	41	20.84 (4.62)	0.603	41	9.56 (7.39)	0.001*	40	41.85 (8.85)	0.002*
14	36	21.31 (4.37)	0.476	36	9.88 (7.14)	<0.001**	33	49.83 (8.18)	<0.001**
15	57	22.56 (4.70)	0.822	57	10.00 (8.05)	<0.001**	57	54.26 (6.90)	<0.001**
16	77	21.62 (2.69)	0.585	77	8.44 (5.02)	<0.001**	77	54.78 (8.23)	<0.001**
17	31	22.69 (4.21)	0.414	31	9.68 (7.76)	0.006*	31	57.95 (6.67)	<0.001**
				Girls					
Age	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*
6	70	16.68 (3.93)	0.445	44	5.06 (2.50)	0.547	44	17.12 (2.28)	0.004*
7	58	16.19 (2.41)	0.150	56	4.85 (2.84)	0.813	56	19.19 (2.57)	0.053
8	50	17.78 (3.52)	0.779	50	7.43 (4.86)	0.062	50	21.94 (4.10)	0.036*
9	51	17.75 (3.73)	0.066	50	8.25 (6.42)	0.848	50	24.79 (3.64)	0.018*
10	49	17.93 (4.23)	0.248	49	8.93 (6.36)	0.765	49	26.94 (4.85)	0.006*
11	69	18.77 (3.18)	0.036*	69	10.03 (5.77)	0.472	69	30.83 (4.55)	<0.001**
12	53	19.93 (3.80)	0.341	53	11.40 (6.47)	0.044*	53	34.20 (4.59)	<0.001**
13	40	20.65 (2.99)	0.603	40	13.96 (8.08)	0.001*	40	36.91 (4.55)	0.002*
14	60	21.91 (3.69)	0.476	60	15.57 (6.63)	<0.001**	60	39.22 (4.24)	<0.001**
15	107	21.93 (3.41)	0.822	107	14.89 (6.51)	<0.001**	107	39.98 (3.61)	<0.001**
16	86	21.88 (3.26)	0.585	86	14.33 (6.80)	<0.001**	86	40.93 (3.45)	<0.001**
17	31	21.85 (3.80)	0.414	31	14.34 (7.49)	0.006*	31	41.17 (3.90)	<0.001**

*$p<0.05$, p-values refer to the differences between boys and girls for analysed measures. BMI: Body Mass Index, FM: Fat mass, FFM: Fat Free Mass.

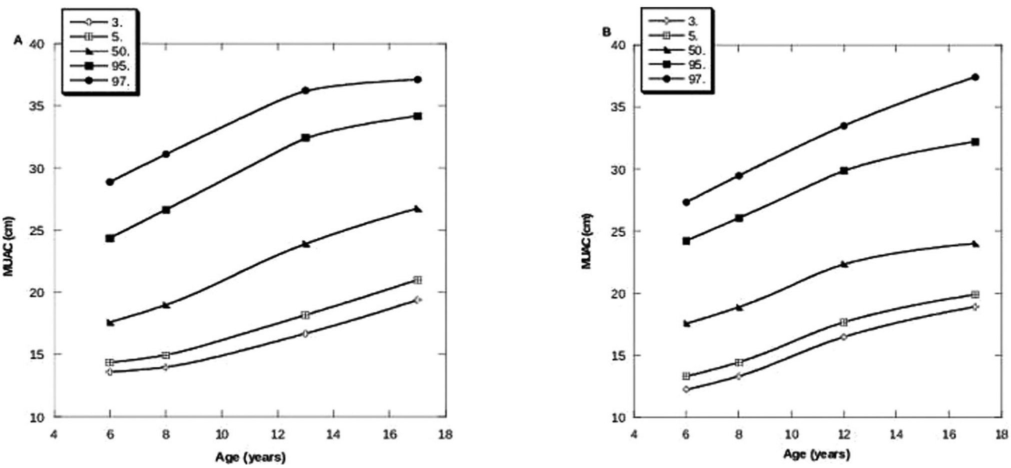

Fig. 1. Selected percentiles of the upper arm circumference in selected ages by sex. A: Boys, B: Girls

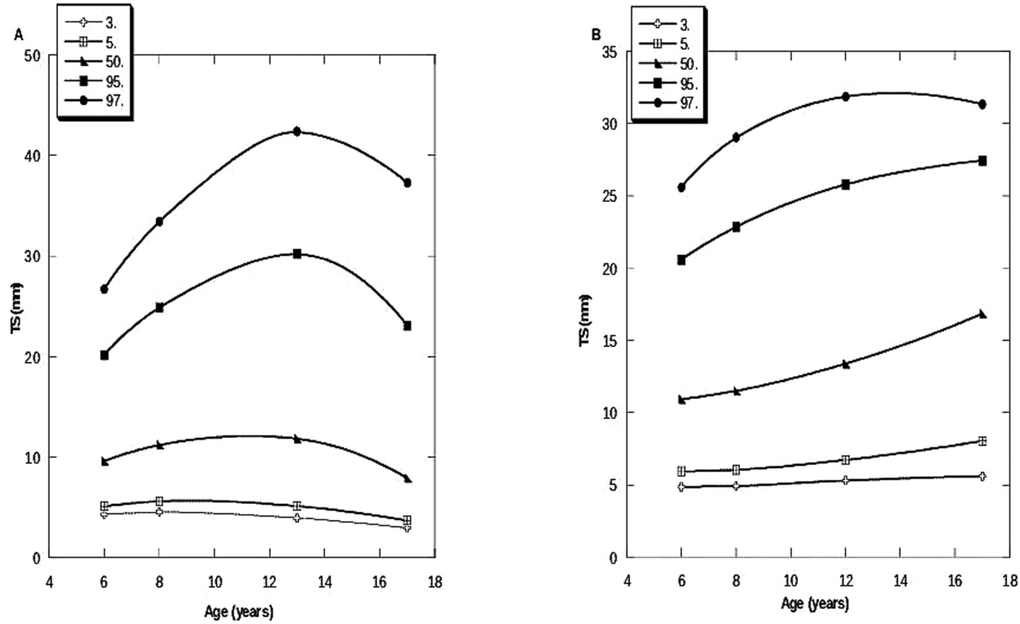

Fig. 2. Selected percentiles of triceps skinfold in selected ages by sex. A: Boys, B: Girls

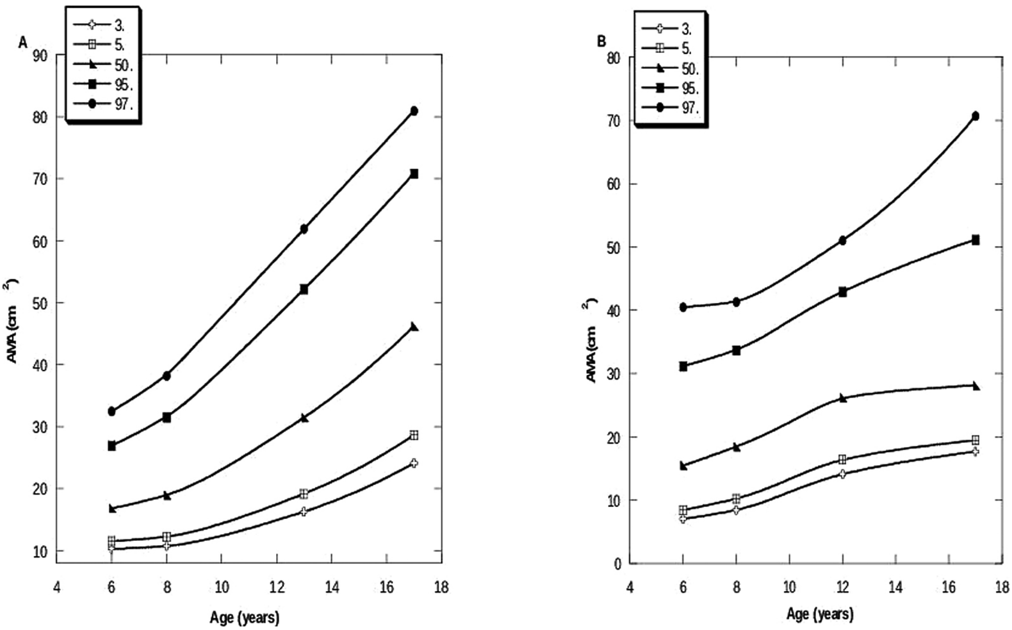

Fig. 3. Selected percentiles of upper arm muscle area (AMA) in selected ages by sex. A: Boys, B: Girls

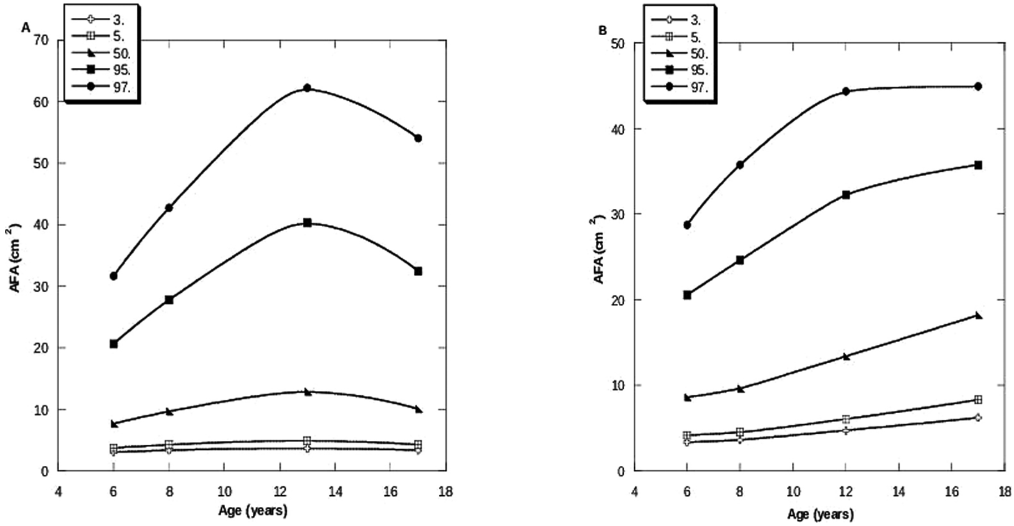

Fig. 4. Selected percentiles of upper arm fat area (AFA) in selected ages by sex. A: Boys, B: Girls

Table 3. Correlation between anthropometric measurements

Measurements	Weight	AMA	AFA	MUAC	BMI	TS	FM	FFM
				Boys				
Height	0.915*	0.848*	0.297	0.762*	0.570*	−0.003	0.380*	0.964*
Weight		0.903*	0.561*	0.912*	0.844*	0.269*	0.677*	0.966*
AMA			0.452*	0.932*	0.749*	0.105*	0.570*	0.903*
AFA				0.719*	0.780*	0.925*	0.826*	0.408*
MUAC					0.883*	0.423*	0.766*	0.851*
BMI						0.569*	0.884*	0.708*
TS							0.685*	0.104*
FM								0.516*
				Girls				
Height	0.860*	0.689*	0.540*	0.679*	0.575*	0.401*	0.648*	0.926*
Weight		0.822*	0.877*	0.880*	0.890*	0.643*	0.908*	0.951*
AMA			0.656*	0.923*	0.786*	0.433*	0.775*	0.779*
AFA				0.884*	0.841*	0.956*	0.853*	0.682*
MUAC					0.888*	0.723*	0.891*	0.806*
BMI						0.737*	0.941*	0.759*
TS							0.753*	0.545*
FM								0.786*

*$p<0.001$, p-values refer to the significance of the correlations between analysed measures. AMA: Upper arm muscle area, AFA: Upper arm fat area, MUAC: mid-upper arm circumference, BMI: Body mass index, TS: Triceps skinfold thickness, FM: Fat mass, FFM: Fat free mass.

Discussion

Nowadays obesity is a global health problem seen both in developed and developing countries. In some developed countries, obesity rates are still high, even in some are stabilized (Lobstein 2015). Alper et al. (2018) determined that obesity rate increased between 1990 and 2015 in children and adolescents aged 5–19 years in Turkey. However, research on this subject is quite limited, and large-scale national researches are needed to demonstrate the obesity trend in Turkish children and adolescents. According to the present results, high correlation was found between BMI and AMA and AFA. The results indicate that body mass index is associated with both fat tissue and muscle tissue. For this reason, only BMI values are not sufficient to determine nutritional status for the children. It can be seen that particularly triceps skinfold thickness values increased until 11 years of age. After this age, triceps skinfold thickness decreased in boys and AFA values decreased from 12 years of age. Triceps skinfold and AFA values were decreased in girls aged 11–12. In boys, subcutaneous fat increases from 7 years to 12–13 years and then declines again, ie the increase in subcutaneous fat before male adolescence is defined as male preadolescent fat wave (Malina and Bouchard 1991; Tanner and Whitehouse 1962). This similarity with the present results may be due to male preadolescent fat wave.

The sum of all skinfolds thicknesses may be an indication of the whole body fat stores and are affected easily by changes that can occur in the diet. Depletion of fat stores at the triceps site is commonly seen in chronically malnourished children. MUAC anthropometric measure reflects both muscle mass and fat stores at upper arm (Mascarenhas et al. 1998; Dougherty and Zemel 2016). Obtained from upper arm circumference and triceps skinfold thickness measurements the arm muscle and fat area give information about protein and calorie reserve (Frisancho 1974; Frisancho 1981). According to the present results, the increase in the upper arm muscle area occurred with increasing age. It should be considered that sex hormones affect the upper arm muscles and fat areas with adolescence. The increase in age also indicates significant sexual dimorphism in upper arm muscle and fat area values. Previous researches also reveal sex difference in upper arm muscle area and upper arm fat area (Sen et al. 2011; Jaswant and Nitish 2014).

In comparison with Iranian adolescents aged 12–17 years, the AMA mean values of girls were lower than the present results for all ages, whereas among boys these values were higher at 13–16 years. AFA values were higher in Iranian adolescents at all ages in both sexes except 12-year-old boys (Al-Sendi et al. 2003). Compared with the results of a survey conducted with 1545 children and adolescents aged 6 to 20 years in India, the AMA and AFA mean values of both sexes were found to be higher in present study (Jaswant and Nitish 2014). Considering the reference values obtained from another study in India, the upper muscle and fat area we obtained in our study are higher than the Indian values (Sen et al. 2011). In Lithuania children aged 5–7 years, AFA values were lower in boys and girls than in our study, but AMA values in girls aged 6 years were higher than in our research. In boys, AMA values were higher in our study (Lipsberga and Každoka 2016). In

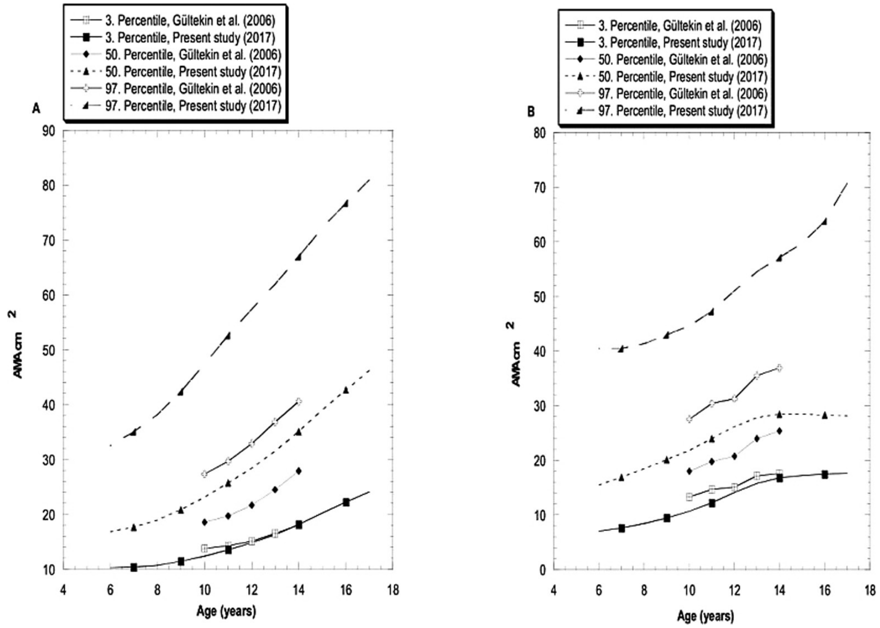

Fig. 5. The comparison of 3rd, 50th, and 97th percentiles of AMA values. A: Boys, B: Girls (Ankara study: Gültekin et al. 2006)

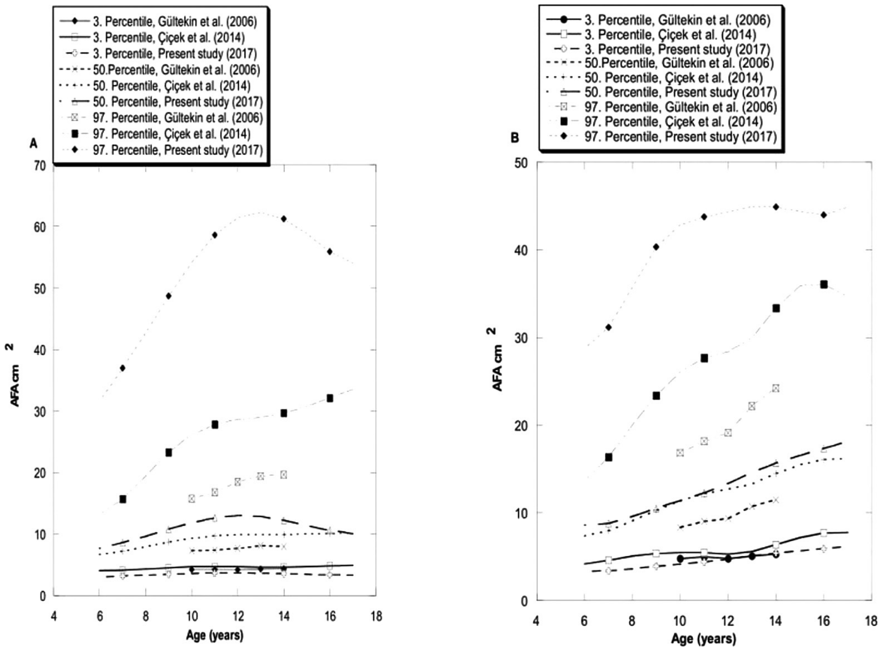

Fig. 6. The comparison of 3rd, 50th, and 97th percentiles of AFA values (Ankara study: Gültekin et al. 2006) (Kayseri study; Çiçek et al.2014) A: Boys, B: Girls

a study conducted with Polish children 7–18 years, it is seen that the MUAC values were higher in both sexes than in our research (Nowak-Szczepanska et al. 2019). It should be noted that MUAC measurements of the sample between 6–17 years of age are lower than the CDC (Centers for Disease Control and Prevention) data (2007–2010) in both sexes. TS values are higher than CDC at 6–9 and 13 years boys and the values lower than CDC except 6 years in girls (Fryar and Ogden 2012).

When the upper arm muscle area 3rd and 97th percentile values compared with Gültekin et al.'s (2006) study conducted in Ankara (Turkey), 3rd percentile values were found to be slightly lower in both boys and girls. However, the present 97th percentile values were found to be higher than Gültekin et al. (2006) values in both sexes. The 3rd percentile values of the upper arm fat area are lower than both the Gültekin et al.' (2006) and Çiçek et al.' (2014) study results for the upper arm fat area. The 97th percentile values were found to be higher in the present study for both sexes (Gültekin et al. 2006; Çiçek et al. 2014) (Figure 5–6). Compared with the previous studies, the 50th percentile values of the upper arm muscle area and fat area were found to be higher in the present study.

Changes in diet can be affected by factors such as globalization, changes in lifestyle, socio-economic level and access to food. It can be stated that since the 1960s, there has been a change in nutritional status all over the world and it is noted that the amounts of energy and macronutrients consumption per capita increase between 1961–2011 year in Turkey (Türközü et al. 2017). Changes in nutrition and lifestyle and at the same time changes in socioeconomic level seems to be a factor affecting the arm anthropometry in Turkey. Especially the increase in AFA values may supports the increasing obesity rates in Turkey.

The main limitation in this research is that this study includes only children and adolescents living in Ankara province. Therefore, it does not reflect the whole country. However, it is thought to be useful in terms of local data. National studies which are large scale and represent the whole country are needed to evaluate the arm muscle and fat area of children and adolescents.

Upper arm muscle area and upper arm fat area were evaluated in Turkish children and adolescents. A high correlation was found between upper muscle area and fat free mass and upper arm fat area and fat mass. Compared to the previous studies conducted in Ankara, AMA and AFA values are increased over time. Present percentiles obtained for Turkish children and adolescents within this study can be thought to be beneficial for providing local data and for future comparison.

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Authors' contributions

Data collecting: CMY, BKÖ; statistical analysis: CMY, BKÖ; article writing: CMY, BKÖ.

Conflict of interest

The authors declare that there is no conflict of interest.

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References

Alper Z, Ercan İ, Uncu Y. 2018. A Meta-Analysis and the Evaluation of Trends in Obesity Prevalence among Children and Adolescents aged 5–19 in Turkey: 1990 through 2015. J Clin Res Pediatr Endocrinol 10(1):59–67.

Al-Sendi AM, Shetty P, Musaiger AO. 2003. Anthropometric and body composition indicators of Bahraini adolescents. Ann Hum Biol 30(4):367–79.

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.

Çiçek B, Öztürk A, Mazıcıoğlu MM, Kurtoğlu S. 2014. Arm anthropometry indices in Turkish children and adolescents: changes over a three-year period. J Clin Res Pediatr Endocrinol 6(4):216–26.

Cole TJ, Green PJ. 1992. Smoothing Reference Centile Curves: The LMS Method and Penalized Likelihood. Stat Med 11:1305–19.

Derman O, Yalçin SS, Kanbur N, Kınık E. 2002. The Influence of the Sexual Stages of Adolescent Boys on the Circumference of the Arm, Muscle Area and Skinfold Measurements. Int J Adolesc Med Health 14(l):19–26.

Dougherty KA. Zemel BS. 2016. Developmental Disabilities. In: C. Duggan, JB Watkins, B Koletzko, and WA Walker, editors. Nutrition in pediatrics. 5th edition. Connecticut: Shelton. 1672–705.

Frisancho AR. 1974. Triceps Skinfold and Upper Arm Muscle Size Norms of Assessment of nutritional Status, Am J Clin Nutr 27(10):1052–8.

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.

Fryar CD, Gu Q, Ogden CL. 2012. Anthropometric reference data for children and adults: United States, 2007–2010. National Center for Health Statistics. Vital Health Stat 11(252).

Gültekin T, Özer BK, Katayama K, Akın G. 2006. Age-related patterns of upper arm muscle and fat area in Turkish children and assessment of nutritional status. Int J Anthropol 21:231–9.

Hacettepe University Institute of Population Studies. 2019. 2018 Turkey Demographic and Health Survey (TDHS). Hacettepe University Institute of Population Studies, T.R. Presidency of Turkey Directorate of Strategy and Budget and TÜBİTAK, Ankara, Turkey.

Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. 2009. Tracking of obesity and physical activity from childhood to adulthood: the physical activity longitudinal study. Int J Pediatr Obes 4(4):281–8.

Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. 1982. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. Am J Clin Nut 36(4):680–90.

Jaswan S, Nitish M. 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.

Lipsberga G, Kažoka D. 2016. Upper-arm anthropometry as nutritional assessment in preschool children in Latvian population. Papers on Anthropology 25(2):25–35.

Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, James, WPT, Wang Y, McPherson K. 2015. Child and adolescent obesity: part of a bigger picture. Lancet 385(9986):2510–20.

Malina RM, Bouchard, C. 1991. Growth, maturation, and physical activity. Champaign IL: Human Kinetics Press.

Mascarenhas MR, Zemel B, Stalling VA. 1998. Nutritional assessment in pediatrics. Nutrition 14(1):105–15.

Must A, Strauss RS. 1999. Risks and consequences of childhood and adolescent obesity. Int J Obes Relat Metab Disord 23:S2–11.

Nowak-Szczepanska, N, Gomula, A, Koziel, S. 2019. Mid-upper arm circumference and body mass index as different screening tools of nutritional and weight status in Polish schoolchildren across socio-political changes. Sci Rep 9:12399.

Öztürk A, Budak N, Çiçek B, Mazıcıoğlu MM, Bayram F, Kurtoğlu 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.

Reilly JJ, Methven E, McDowell ZC, Hacking B, Alexander D, Stewart L, Kelnar CJH. 2003. Health consequences of obesity. Arch Dis Child 88(9):748–52.

Rolland-Cachera M. 1993. Body composition during adolescence: methods, limitations and determinants. Horm Res 39(3):25–40.

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.

Tanner JM, Whitehouse RH. 1962. Standards for subcutaneous fat in British children. Percentiles for thickness of skinfolds over triceps and below scapula. Br Med J 1(5276):446–50.

Türközü D, Ayhan B, Köksal E. 2017. The nutrition transition in Turkey: trends in energy and macronutrients supply from 1961 to 2011. GMJ 28(4):283–8.

Weiner J, Lourie JA. 1969. Human Biology: A guide to field methods IBP Handbook. Oxford: Blackwell.

World Health Organization. 2016. Report of the Commission on Ending Childhood Obesity. Geneva: World Health Organization 2016.

World Health Organization. 2019a. Obesity and overweight. Available at: http://www.who.int/mediacentre/factsheets/fs311/en/ [Accessed 24 march 2019]

World Health Organization. 2019b. Malnutrition. Available at: https://www.who.int/news-room/fact-sheets/detail/malnutrition, [Accessed 24 march 2019]

Zemel B. 2002. Body Composition During Growth and Development, In: N. Cameron, editor. Human Growth and Development. California: Academic Press, 271–329.