Original Article

Body Composition Reference Percentiles of Healthy Iranian Children and Adolescents in southern Iran

Marjan Jeddi MD[1], Mohammad Hossein Dabbaghmanesh MD•[1], Gholamhossein Ranjbar Omrani MD[1], Sayed Mohammad Taghi Ayatollahi PhD[2], Zahra Bagheri PhD[2], Marzieh Bakhshayeshkaram MD[1]

Abstract

Background: The prevalence of childhood obesity has risen greatly worldwide. However, assessment of obesity among children and adolescents is further complicated by the changes occurring in the body composition during the growth. The aim of this study is to create gender-specific percentile curves for total body fat percentage (TBFP), total body fat mass (TBFM), fat mass index (FMI), and fat free mass index (FFMI) in healthy Iranian children and adolescents.

Methods: In this cross-sectional study, 472 healthy Iranian children and adolescents (234 girls and 238 boys) aged 9–18 years old participated. TBFP and TBFM were measured by Dual-Energy X-ray Absorptiometry (DEXA). Weight, height, and waist circumference (WC), pubertal stage and level of physical activity were also recorded.

Results: Mean TBFM, TBFP and FMI in girls were significantly more than boys ($P < 0.001$). The median TBFM in boys increased from 4.8 Kg to 7.5 Kg and in girls from 6.0 Kg to 15.6 Kg. The percentile curves of TBFP in boys were down sloping compared with that in girls (19% increase in girls and 21% decrease in boys from 9–18 years of age).

We showed TBFP and FMI had a more complicated relationship with BMI depending on gender and level of BMI, but FFMI consistently increased with BMI in both genders. Also, we found that waist circumference –as a marker of metabolic syndrome-had the greatest correlation with FMI ($P < 0.001$) between DEXA measured parameters.

Conclusion: This study presents normative data for body composition in healthy Iranian children and adolescents and would be useful in adiposity assessment. Our study showed that Iranian children and adolescents had lower total body fat in all age groups and percentiles in comparison with those reported from western children.

Keywords: Body composition, dual-energy X-ray absorptiometry, percentile curve

Cite this article as: Jeddi M, Dabbaghmanesh MH, Ranjbar Omrani G, Ayatollahi SMT, Bagheri Z, Bakhshayeshkaram M. Body Composition Reference Percentiles of Healthy Iranian Children and Adolescents Aged 9–18 Years in southern Iran. *Arch Iran Med*. 2014; **17(10):** 661 – 669.

Introduction

Obesity is an important metabolic problem of the recent century. The problem of childhood obesity is worsening in many countries at a dramatic rate.[1] Therefore, assessment of obesity in children and adolescents is important. One of the main components to consider in assessment of obesity is body composition. The total body fat mass and its distribution have been known to be important determinants in far-ranging *negative* effects of obesity on health.[2]

Metabolic disorders are directly correlated to obesity and body composition. Obesity is a risk factor for DM type 2, cardiovascular disease, non-alcoholic fatty liver and metabolic syndrome.[3]

Among many direct and indirect methods to evaluate adiposity, Body Mass Index (BMI) is being used as a most popular index, because of its simplicity, low cost and widely accepted reference values in children and adolescents.[4,5] However, several authors have addressed its limitation: BMI cannot distinguish between fat and lean mass; BMI is not always an accurate predictor of fat distribution and its use for characterizing adiposity differs among different ethnic groups because of an alteration in body-fat proportions.[6–8]

During childhood and adolescence, both fat mass and lean mass are increasing.[9] BMI and waist circumference (WC) are independent predictors of body fat percentile in adults,[9] but it's still uncertain whether these two indices can predict body fat percentage in children.[10] Waist circumference assessment has been used to estimate intra-abdominal fat and may be useful in evaluation of childhood obesity.[11]

Among available methods measuring fat mass and lean mass, dual-energy X-ray absorptiometry (DEXA) is the most widely used and can quantify the regional fat and lean tissue mass.[12] This technique is also an ideal for children, because it delivers a very small dose of radiation.[13] Thus, several countries have recently measured body fat by DXA in children and adolescents and tried to provide its age- and gender-specific percentile values for references.[14–16]

Few studies have been conducted on the prevalence of obesity in the Iranian population[17–20]; however we do not have normative body composition percentiles for Iranian children and adolescents. Therefore, we conducted this study to provide gender- and age-specific reference percentile curves for body composition in

Authors' affiliation: [1]Endocrine and Metabolism Research Center, Shiraz University of Medical Sciences, Shiraz, Iran. [2]Department of Biostatistics, Shiraz University of Medical Sciences, Shiraz, Iran.

•Corresponding author and reprints: Mohammad Hossein Dabbaghmanesh MD, Endocrine and Metabolism Research Center, Nemazee Hospital, Shiraz University of Medical Sciences, Shiraz, Iran. P. O. Box: 71345-1414, Shiraz, Iran. Fax: +98-711-647-3096,
E-mail: dabbaghm@sums.ac.ir

Accepted for publication: 1 September 2014

this population. Additionally, our data can be used in determining adiposity distribution in Iranian children and comparison with other studies.

Materials and Methods

Subjects

This cross-sectional study is the first study in Iran that was conducted to measure body composition by DXA. We studied in apparently healthy Iranian children and adolescents 9–18 years old in Kawar, an urban community located about 50Km east of Shiraz, the capital of Fars Province in southern Iran. Our subjects were girls and boys aged 9–18 years who were pupils of elementary, guidance, or secondary schools. By systematic random sampling we selected our sample group. An age-stratified systematic random sample of 7.5% was applied, and eventually 472 subjects (234 girls and 238 boys) participated in this study. We selected our samples randomly from all of the elementary, guidance, and secondary schools of this community according to student numbers in each age group. We selected units at a fixed interval throughout the sampling frame after a random start. An endocrinologist examined all subjects; Tanner stage of puberty was distinguished, and each participant with the major chronic disorder was excluded. We divided our subjects into two groups with less than or more than three times physical activity weekly (physical education classes, organized sports, recreational activity, regular walking, or cycling) per week according to their or their parents' views.[21,22] The study was approved by the ethics committee of Shiraz University of Medical Sciences. Consent forms were obtained from the parents of all participants.

Anthropometry

Weight was measured with a standard scale to the nearest 0.1 Kg (Seca, Germany) and height was measured with a wall-mounted meter to the nearest 0.5 cm in all subjects wearing light clothing and bare-footed. A waist circumference was measured at the level of the umbilicus to the nearest millimeter. BMI (Kg/m^2) was calculated by dividing weight (Kg) by height^2 (m^2). We divided our subjects to overweight and obese with BMI greater than the 85th percentile and 95th percentile, respectively.[23] Based on our subjects' BMI cutoff points and also age-and sex-specific BMI cut-off points as defined using International Obesity Task Force (IOTF) cutoffs.[24]

Body composition assessment

The Hologic system (Discovery QDR, USA) was used to measure TBFM in gram and TBFP. Total body Fat Free Mass (FFM) was measured by DEXA as total body bone mineral content in addition to total body lean mass.[25] DEXA study was done with the participants wearing special clothing and shoes. Scanner stability was checked throughout the course of the study with plots of daily spine phantom scans. We calculated FMI (Kg/m^2) by dividing total fat mass (Kg) by height (m^2) and FFMI by dividing fat free mass (Kg) by height (m^2). The coefficient of variation (CV) in our laboratory was 0.7% for fat mass, and 1.9% for fat percentage and lean mass.

Statistical methods

Statistical analysis including: Student *t*-test, Mann-Whitney Test, multivariate linear regression analysis, and Pearson correlation, all being done in SPSS V.18 and Medcalc V.8 software. A *P* value < 0.05 was considered significant.

The Lambda for skew, Mu for median and Sigma for generalized coefficient of variation (LMS) method were used to calculate smoothed weight, height, BMI, TBFM, TBFP, FMI, and FFMI curves for age centiles. LMS Chart Maker[26–28] and Excel software were used to construct the gender-specific reference plots showing 5, 25, 50, 75, 85, and 95th percentiles of BMI, TBFM, TBFP, FMI, and FFMI. Then gender specific relationship between BMI, waist circumference and body fat measures were determined by locally weighted regression scatter plot smoothing.[29]

Results

Table 1 shows the mean and standard deviation (SD) for weight, height, waist circumference, BMI, TBFM, TBFP, FMI, and FFMI in each age group of boys and girls. In this study mean age of boys was 13.8 years old and mean age of girls were 13.7 years old (*P* =0.89). Girls had the mean weight of 41.5 ± 11.9, mean height of 150.7 ± 11.6, mean waist circumference of 69.4 ± 10.1, and mean BMI of 17.9 ± 3.3. In boys, the mean weight was 44.7 ± 14.5, mean height 157.3 ± 15.9, mean waist circumference 67.5 ± 10.4, and mean BMI 17.5 ± 3.0.

We divided our subjects to overweight and obese with BMI greater than the 85th percentile and 95th percentile, respectively based on our subjects' BMI cutoff points. We found that 11.3% of boys and 11.0% of girls were overweight (BMI > 85 percentile) and 5.4% of boys and 4.2% of girls were obese (BMI > 95 percentile). According to IOTF cutoffs, we found that 6.3% of boys and 5.5% of girls were overweight and only 0.4% of girls were obese.

Boys were taller and heavier than girls (*P* < 0.001), but there was no significant difference between their BMI (*P* = 0.19). The waist circumference of 12–14-year-old girls was more than that of boys (*P* = 0.04, 0.01, 0.002) and in the other age groups, Significant change between two genders was not observed.

Mean TBFM in 18-year-old girls was more than twice in 9-year-old girls. In boys, we detected about 75% increase in TBFM between 9–18 years of age. Mean TBFP in 9-year-old girls was 25.3% and in 18-year-old girls it was 30.3% that showed 19% increase; On the other hand, 9-year-old boys had a mean TBFP of 18.1% in comparison to 14.2% in 18-year-old boys that indicates 21.3% decrease. Boys exhibited an early rise and then fall in TBFP with age. Also, mean FMI in boys was 3.1 kg/m^2 and in girls it was 5.1 kg/m^2. Mean FFMIs in boys and girls were 14.5 kg/m^2 and 13.1 kg/m^2, respectively.

In girls, FMI and FFMI significantly increased between 9–18 years of age (*P* = 0.03 and *P* = 0.001); however, in boys only the rise in FFMI was significant (*P* < 0.001) and FMI had no significant change (*P* = 0.8).

As a general rule, mean TBFM, TBFP and FMI in girls was significantly more than boys (12 Kg vs. 8 Kg, 27% vs. 17% and 5.1 vs. 3.1), respectively (all *P* < 0.001); however, the mean FFMI was 14.5 in boys in comparison to 13.1 in girls (*P* < 0.001). Table 2 shows 5th and 95th percentiles for BMI, TBFP, FMI, and FFMI.

Total body fat mass and total body fat percent percentiles

Figure 1 illustrates the reference percentile curves obtained for TBFM and TBFP for boys and girls by age (Figure 1). The median TBFM in boys increased from 4.8 Kg to 7.5 Kg and in girls from 6.0 Kg to 15.6 Kg in 9–18 years of age. The 95th percentile

Table 1. Anthropometric parameters and mean level of body composition in the study population.

Age (years old)	Boys									Girls								
	Number (%)	Weight (Kg)	Height (m)	BMI (Kg/m²)	Waist Circumference (cm)	TBFM (Kg)	TBFP (%)	FMI (Kg/m²)	FFMI (Kg/m²)	Number (%)	Weight (Kg)	Height (m)	BMI (Kg/m²)	Waist Circumference (cm)	TBFM (Kg)	TBFP (%)	FMI (Kg/m²)	FFMI (Kg/m²)
9	11(4.6)	26.0±3.6	131.2±4.1	15.0±1.5	55.5±3.9	4.9±1.7	18.1±4.3	2.8±0.9	12.5±1.0	9(3.9)	26.4±5.5	129.0±6.0	15.7±2.2	57.7±6.1	7.4±3.9	25.3±6.8	4.3±1.9	12.2±0.6
10	21(8.8)	29.5±4.2	136.2±5.9	15.8±1.5	59.6±6.2	6.4±2.9	20.8±6.3	3.4±1.3	12.6±0.9	27(11.7)	28.3±4.7	134.6±6.7	15.6±1.9	58.9±5.4	7.3±2.2	24.7±4.0	4.0±1.2	12.0±2.0
11	23(9.7)	30.7±4.4	139.0±6.3	15.9±1.9	60.2±6.9	6.1±2.5	19.1±5.1	3.1±1.3	12.9±1.0	26(11.3)	29.6±5.7	139.0±8.6	15.2±1.6	60.8±5.4	8.4±3.7	25.3±6.0	4.3±1.9	12.3±1.7
12	22(9.3)	34.5±5.3	145.5±5.2	16.2±2.2	60.6±6.2	6.6±2.8	18.8±5.4	3.1±1.3	13.0±0.9	26(11.3)	35.6±6.5	148.9±7.6	16.0±2.0	65.0±7.9	9.6±3.9	25.3±6.2	4.3±1.6	12.3±1.1
13	25(10.5)	40.4±8.0	153.9±7.7	16.9±2.6	64.0±8.4	8.7±4.7	19.8±7.3	3.6±1.9	14.0±1.4	25(10.8)	42.5±9.4	153.8±5.5	17.8±3.0	69.4±6.5	11.2±4.2	25.3±5.7	4.6±1.5	13.3±1.2
14	33(13.9)	44.7±11.6	160.3±10.0	17.1±3.0	66.0±9.0	8.6±4.8	17.7±5.6	3.3±1.6	14.6±2.0	27(11.7)	45.8±8.7	154.9±5.8	19.0±2.7	72.2±6.5	13.6±6.0	29.5±6.6	5.6±2.2	13.5±1.4
15	32(13.5)	52.3±9.4	168.3±7.6	18.4±2.7	72.1±9.0	8.8±5.2	16.0±6.6	3.1±1.7	15.3±1.6	21(9.1)	48.4±6.5	159.5±4.7	19.0±2.4	75.1±8.5	14.2±3.7	28.8±5.0	5.5±1.4	13.5±1.6
16	28(11.8)	55.0±11.2	169.7±7.2	18.9±2.9	75.8±7.7	8.3±4.7	14.9±4.9	2.8±1.4	15.5±1.6	23(10.0)	52.4±9.1	158.5±5.6	20.8±3.3	79.5±8.8	16.3±5.6	30.4±5.4	6.4±2.1	14.2±1.7
17	19(8.0)	61.0±12.4	173.1±4.6	20.3±4.0	78.4±7.0	9.6±5.5	15.2±6.1	3.2±1.8	16.7±2.3	22(9.5)	48.2±12.6	158.9±5.5	19.2±4.3	78.1±9.1	15.3±6.6	30.1±6.1	6.2±2.3	13.4±1.6
18	22(9.3)	60.1±11.3	175.8±6.5	19.3±3.0	75.4±8.9	8.6±4.0	14.2±4.9	2.7±1.2	16.2±2.2	24(10.4)	51.3±7.0	160.1±5.6	20.0±2.6	74.0±7.9	15.0±4.4	30.2±6.7	5.8±1.7	13.8±1.2

Table 2. Smoothed percentiles (5th and 95th) for BMI, TBFP, FMI, and FFMI among boys and girls.

Age (years)	Percentile for Boys								Percentile for Girls							
	BMI		TBFP		FMI		FFMI		BMI		TBFP		FMI		FFMI	
	5th	95th	5th	95th	5th	95th	5th	95th	5th	95th	5th	95th	5th	95th	5th	95th
9	13.23	17.98	14.14	28.41	1.97	5.13	11.34	13.58	12.42	18.54	17.76	32.32	2.46	5.90	10.20	13.80
10	13.41	18.80	13.75	28.19	1.96	5.18	11.40	13.93	12.70	19.29	18.27	32.67	2.58	6.15	10.45	14.06
11	13.50	19.52	13.31	27.86	1.94	5.22	11.53	14.37	13.02	20.11	18.81	33.11	2.71	6.43	10.72	14.37
12	13.58	20.26	12.79	27.34	1.92	5.23	11.78	14.97	13.44	21.11	19.42	33.72	2.87	6.77	11.02	14.70
13	13.77	21.17	12.17	26.58	1.88	5.20	12.18	15.79	13.93	22.25	20.13	34.50	3.07	7.20	11.32	15.04
14	14.11	22.36	11.45	25.56	1.81	5.12	12.63	16.68	14.39	23.39	20.87	35.36	3.28	7.69	11.58	15.33
15	14.55	23.75	10.70	24.44	1.74	4.99	13.02	17.54	14.75	24.39	21.53	36.08	3.48	8.14	11.79	15.55
16	14.96	25.13	10.01	23.40	1.67	4.87	13.33	18.31	14.97	25.21	22.05	36.56	3.65	8.51	11.95	15.71
17	15.26	26.38	9.40	22.49	1.60	4.77	13.57	19.02	15.05	25.85	22.43	36.81	3.78	8.81	12.08	15.83
18	15.48	27.52	8.83	21.65	1.55	4.69	13.76	19.66	15.05	26.39	22.72	36.91	3.89	9.06	12.20	15.94

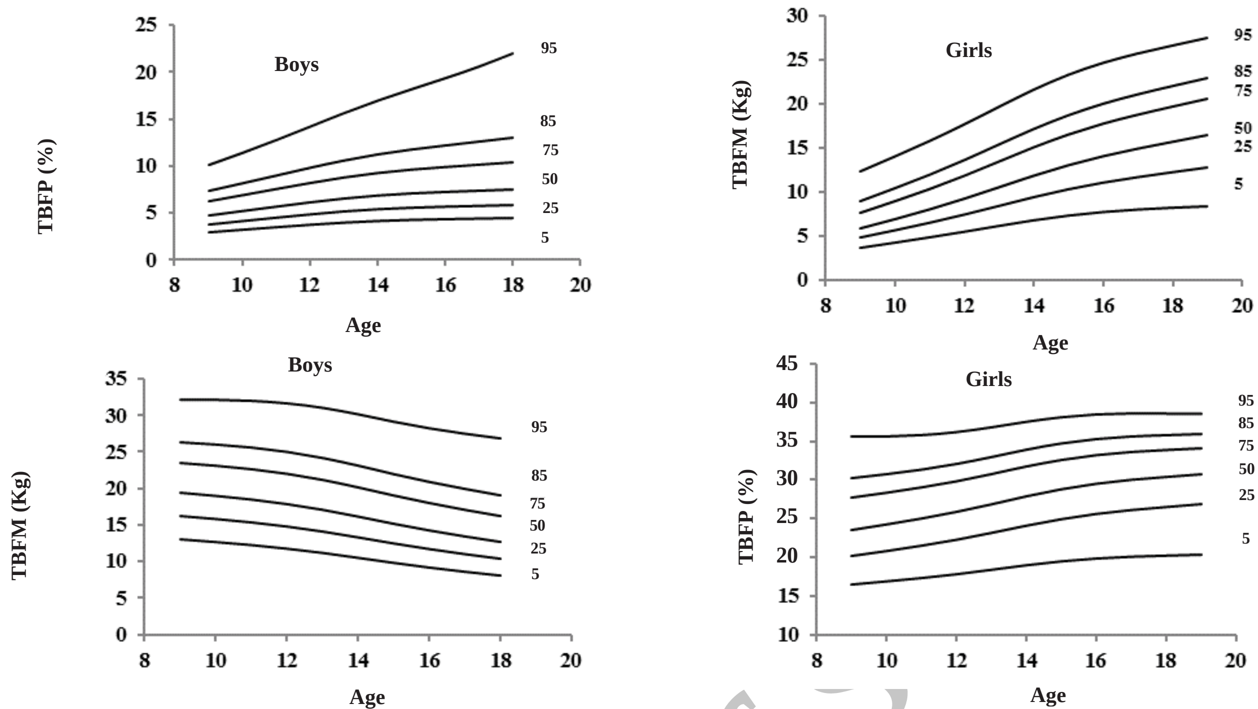

Figure 1. Reference percentile curves for TBFM and TBFP in the study population by age.

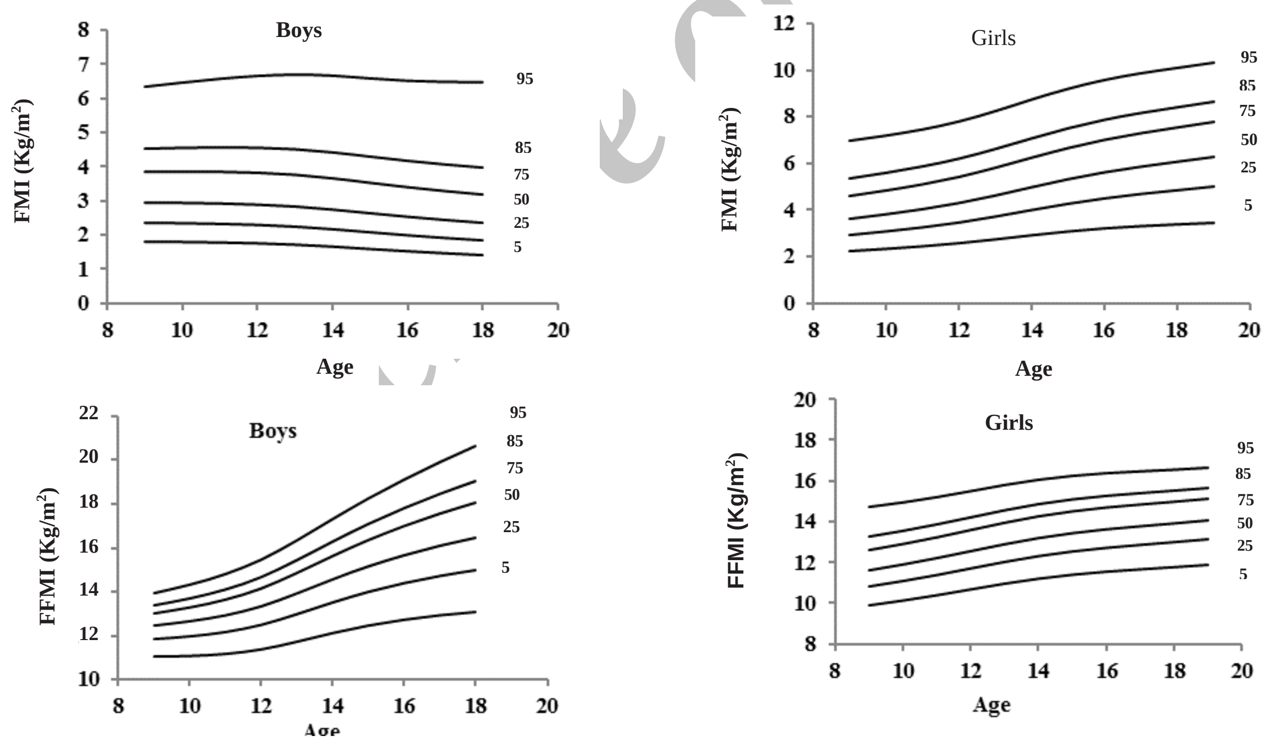

Figure 2. Reference percentile curves for FMI and FFMI in the study population by age.

curves of TBFM in boys diverged more from the 50th percentile curves, whereas in girls the rise in TBFM in the 50th and 95th percentile curves are in a similar manner.

Percentile curves of TBFP in boys are down sloping with median of 19.3% in 9-year-old boys and 12.6% in 18-year-old boys, whereas the median TBFP in girls has been increased about 30% from 9–18 years (23.5% in 9-year-old girls and 30.3% in 18-year-old girls) and curves were up-sloping. TBFM was associated with age (r = 0.24), weight (r = 0.65), height (r = 0.33), and BMI (r = 0.80) in boys as well as in girls, age (r = 0.54), weight (r = 0.83), height (r = 0.58), and BMI (r = 0.81) ($P < 0.001$).

Table 3. Mean level of body composition in different stages of puberty.

Puberty	Boys					Girls				
	Number	TBFM (Kg)	TBFP (%)	FMI (Kg/m²)	FFMI (Kg/m²)	Number	TBFM (Kg)	TBFP (%)	FMI (Kg/m²)	FFMI (Kg/m²)
Early	89	6.7±3.5	19.9±5.9	3.3±1.5	12.8±1.1	57	7.4±2.5	24.9±5.1	4.0±1.2	11.8±0.9
Mid	83	8.5±4.6	16.6±5.6	3.1±1.5	15.0±1.8	67	11.6±4.8	26.5±6.3	4.9±1.8	13.1±1.4
Late	47	8.8±5.0	14.6±5.9	2.9±1.6	16.3±1.7	93	15.2±5.2	30.2±5.8	6.0±1.9	13.8±1.5

Table 4. The effect of age, gender, stage of puberty and BMI on TBFM.

	Regression coefficient	SE	Sig
constant	-12.36	1.16	<0.001
Age	0.03	0.11	0.78
Sex	-3.61	0.28	<0.001
Stage of Puberty	-0.03	0.20	0.86
BMI	1.34	0.05	<0.001

Table 5. The effect of age, gender, stage of puberty and BMI on Total body lean mass.

	Regression coefficient	SE	Sig
constant	-8077.2	2007.7	<0.001
Age	237.7	199.5	0.23
Sex	8322.8	489.8	<0.001
Stage of Puberty	3205.5	354.6	<0.001
BMI	1241.0	87.3	<0.001

Table 6. The effect of age and body composition on waist circumference.

	Boys			Girls		
	Regression Coefficient	SE	Sig.	Regression Coefficient	SE	Sig.
Constant	10.12	2.79	<0.001	26.11	3.82	<0.001
Age	1.71	0.21	<0.001	1.56	0.17	<0.001
FMI	1.87	0.28	<0.001	1.82	0.28	<0.001
FFMI	1.91	0.27	<0.001	0.94	0.34	<0.001

Fat mass index and fat free mass index percentiles

Reference percentile curves derived for FMI and FFMI for boys and girls by age are shown in Figure 2. The median FMI in boys was approximately constant and the remaining was near 2% from 9–18 old of age with relatively flat percentile curves; but 18-year-old girls had almost twice as much FMI as 9-year-old girls (6.0 vs. 3.6) and the percentile curves were up-sloping. The 50th percentile of FFMI in girls was relatively flat, but in boys it increased till the age of 18. The maximum rise in mean FFMI in boys developed from 12–18.

FMI in boys was associated only with weight (r = 0.35) and BMI (r = 0.65), whereas in girls it was associated with age (r = 0.39), weight (r = 0.67), height (r = 0.34), and BMI (r = 0.75) (P < 0.001). FFMI in boys was associated with age (r = 0.62), weight (r = 0.86), height (r = 0.67), and BMI (r = 0.83), and in girls with age (r = 0.40), weight (r = 0.69), height (r = 0.41), and BMI (r = 0.74) (P < 0.001).

Body composition and puberty

According to Tanner stages of puberty, subjects in this study were divided into early (Tanner stage 1 and 2), mid (Tanner stage 3 and 4) and late (Tanner stage 5) puberty. Table 3 displays the mean ± SD for TBFM, TBFP, FMI, and FFMI in various stages of puberty.

Between early and mid-puberty TBFM, FMI, and FFMI significantly increased in girls (P = 0.001, 0.001 and 0.002), but in boys only TBFM and FFMI had a significant rise (P = 0.004 and 0.001) and TBFP significantly decreased (P = 0.001). In comparison, between mid and late puberty period, all parameters in girls were significantly rising (P < 0.05), whereas in boys only FFMI significantly increased (P = 0.001) and the change in the other parameters was not significant.

We compared TBFM, TBFP, FMI, and FFMI between boys and girls in different stages of puberty. All parameters in girls were greater than those of boys in all stages of puberty (P = 0.001) except FFMI that was generally higher in boys than girls (P = 0.001).

Body composition and physical activity

We divided our subjects into two groups with less than or more than three times physical activity per week. Boys accomplished more exercise than girls. In this study, 52.1% of boys participated in physical activities three times per week or more compared to 9.8% of the girls.

In comparison of body composition in these two groups, we found that boys with more physical activity had a higher FFMI

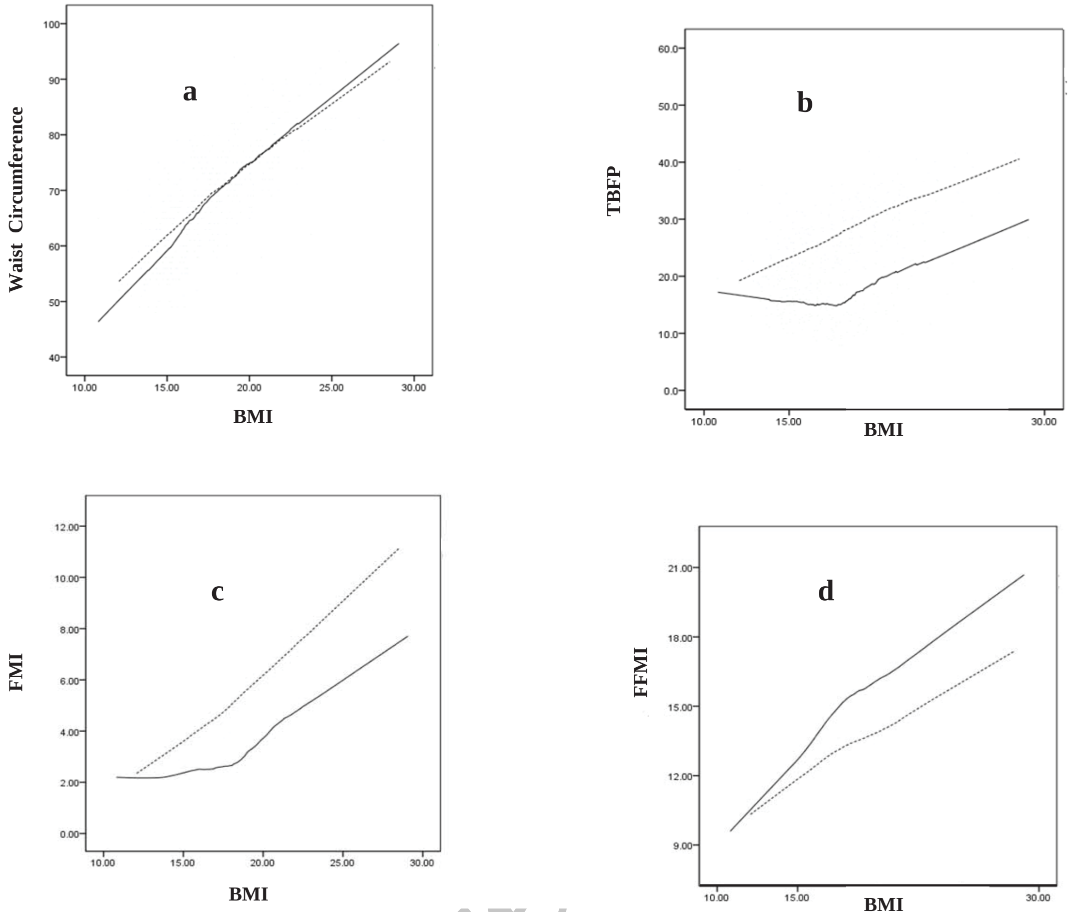

Figure 3. The gender-specific relationship between waist circumference and BMI **(a)** and body-fat measures and BMI **(b – d)** girls…….., boys

than those with less physical activity (14.9 ± 2.1 vs. 14.0 ± 2.0) (P = 0.001); also the first group had less TBFP than the second group (16.6 ± 5.8 vs. 18.2 ± 6.2) (P = 0.03). We didn't find any significant difference in body composition measures in girls with more or less than three times physical activity per week.

Body composition and BMI

The relationship between BMI, waist circumference, TBFP, FMI, and FFMI has been shown in Figure 3. There was a relationship between BMI and waist circumference in both genders and in all levels of BMI; waist circumference increased with the rise in BMI.

Correlation of BMI with TBFP and FMI in boys and girls were different. In girls TBFP increased with BMI rising. In boys only in BMI greater than 18 kg/m^2 TBFP increased and before that decreased; but, FFMI depicted a direct relationship with BMI in both genders.

In multivariate linear regression analysis, we showed that age, gender, stage of puberty, and BMI predicted 73% of change in TBFM and 76% in total lean mass; we also found that sex, age, fat mass and fat free mass predicted 70% of change in waist circumference (P < 0.001). According to our results, with each one kg/m^2 increase in FMI, change in waist circumference in girls and boys was 1.8, but this change for each one kg/m^2 rise of FFMI was 0.9 and 1.9 in girls and boys respectively (P < 0.001) (Tables 4, 5, and 6).

Also, we evaluated the correlation between waist circumference –as a marker of metabolic syndrome- and BMI (r = 0.78), TBFP (r = 0.32), trunk fat percent (r = 0.36) and FMI (r = 0.49) (all P < 0.001); we found that waist circumference had the greatest correlation with FMI (P < 0.001) among the DEXA measured parameters.

Discussion

In this cross-sectional study, for the first time, we have evaluated body composition in Iranian children and adolescents. We have also presented age and gender specific reference percentile curves for TBFM, TBFP, FMI, and FFMI using DXA-derived measures. These smoothed curves can be used to show differences in the body fat between different ethnic groups.

Effect of ethnicity

We compared anthropometric measures of Iranian children and adolescents with participants of the same age group from Korea[30] and Ohio.[31] According to our findings, our subjects had a lower mean weight, height, and BMI than their participants. We determined the rate of obesity, according to our study percentile cutoffs and IOTF cut-offs and found a lower rate of overweight and obesity according to IOTF cutoffs in comparison to our study BMI cutoffs. Pandit and coworkers in India also showed a lower percentage of obese children as defined by the BMI cutoffs of the IOTF than that using Indian cutoffs.[32] Prevalence of obesity in our subjects was lower than the Indian and the USA participants.[32,33] Also we compared our results with the result of other studies in Iran. Rahmanian and coworkers in 2013 reported 9.1% obesity and 7.5% overweight in Iranian children and adolescents in CASPIAN-III study.[20] In the study of Mohammadpour, the overall prevalence of overweight and obesity were 21.1 and 7.8% in Tehran City.[19] The difference between these and our results seems to be due to different area of these studies and also different cut-offs for definition of obesity.

Iranian children and adolescents had lower mean TBFP than children and adolescents of the same age group in Korea.[30] and India[34] ($P < 0.001$). We compared the 5th, 25th, 50th, 85th, and 95th percentiles of TBFP in our Iranian subjects and American counterparts in NHANES's study[35] and found that Iranian children and adolescents had lower TBFP in all age groups and in all percentiles. Also we showed that total fat mass in Iranian children was lower than that of their participants in London and the southeast of England.[36]

Mean FFMI of Iranian boys was lower than that of boys in Korea,[30] Ohio,[31] and Chinese boys[37] (all $P < 0.001$), but mean FFMI of Iranian girls was only lower than that of Ohio girls[(31)] ($P < 0.001$) and had no significant difference with girls in China[37] and Korea[30] ($P = 0.1$, $P = 0.3$). Lower mean FFMI in Iranian boys is the same as the lower total body BMC and BMD that we showed in the previous study.[22]

Effect of gender

In our study, although we didn't find any important difference between BMI in the two genders, TBFM, TBFP and FMI in girls were more than boys. TBFP curves in girls were relatively increased between 9–18 years of age, whereas in boys TBFP had a diminished pattern in this age group. The same pattern has been observed in other studies.[14,30,35,37,38] Kurtoglu and coworkers in a study on body fat measurement by a segmental body composition analyzer on Turkish Children and Adolescents found that body fat percentage of girls was significantly higher than boys.[38] Data obtained from NHANES also showed a drop in body fat percentage of boys in early adolescence, especially at the higher percentiles and a slow increase in body fat percentage of girls in the same age.[35]

We found different trends of change in FFMI curves between the two genders, showing that FFMI curves in girls was relatively flat, but in boys it had a rising pattern with a maximum increase in 12–18 years of age. This finding was also shown in Ohio,[31] Canada,[16] and China.[37]

During normal growth, boys gain more muscle mass and girls gain more fat mass.[39] In both genders the predominant composition of BMI is fat free tissue (in our study FFMI is about 2.5–4.5 times greater than FMI) and it seems that the rise of BMI is predominantly related to fat free mass in growing children, especially in boys. Kirang Kim in Korea[30] and Demerath, et al., in Ohio[31] also showed that age-related increase in BMI during childhood was attributed to increasing fat free mass rather than fat mass.

The cause of gender differences in fat patterning before puberty is not well known.[40] A part of these differences can be explained by the effect of insulin-like growth factor 1, dehydroepiandrosterone sulfate and leptin on fat percentage. However, these hormonal effects explained < 20% of sexual dimorphism in fat distribution.[41]

Effect of Puberty

With the onset of puberty, we found important differences in measures of body fat between boys and girls. Fat percentages of girls were increased during puberty but in boys it was decreased. Kirang Kim, et al., in Korea measured the body fat by DEXA and found a decrease in TBFP in boys during early adolescence and increase in girls in the period of late adolescence.[30] Also in China, Wang, et al., showed an increase in muscle mass and central adipose tissue in boys and an increase in body fat mass, primarily peripheral adipose tissue, in girls during adolescence.[40] Previous studies have referred to sexual dimorphism in body composition at birth to a small degree, but important differences develop during puberty that is largely regulated by growth hormone and gonadal steroids (Testosterone in boys and estradiol in girls).[40,42]

Relationship between BMI and Body Composition

In this study, we evaluated the relationship between DEXA-based body fat measurement with BMI and waist circumference. We considered whether BMI or waist circumference can be used as a substitute of body fat for estimation of obesity and its complication.

We demonstrated that in girls, BMI correlates well with TBFP, but in boys, especially in BMI lower than 18 kg/m^2, TBFP and BMI don't reflect an accurate correlation. This could be explained by different body composition in the two genders, particularly during puberty; although in studies of American children and adolescents, BMI was highly correlated with the percentage of body fat in both genders.[43] The correlation between BMI and TBFP is stronger in higher BMI measures[43] and our subjects had a lower rate of overweight and obesity in comparison to American counterparts.[33] The leanness of the Iranian children and adolescents may cause this discrepancy.

Waist circumference is characteristic of the metabolic syndrome[44] and its complications. Lee, et al., in their study found that waist circumference is associated with total body fat and insulin sensitivity.[45]

In this study, we evaluated the relationship between waist circumference and body composition values measured by DEXA and found that waist circumference had the greatest correlation with FMI between DEXA measured body fat parameters. DEXA can separate body mass into fat mass and lean mass; therefore, measurement of body fat in this method is performed without the confounding effect of other tissue components.[46]

Using FMI for evaluation of adiposity and permitting fat mass assessment without interference from other components such as muscle or water. Thomas L. Kelly, et al., proposed the use of FMI as a parameter of low or excess fat in children.[46]

Limitation

This study had a number of limitations. The main limitation was its cross-sectional design. Future prospective studies are needed to validate our observations.

Another important limitation of our study is that the comparisons between the data obtained with different methods must be made with caution because variations between different modalities may result in substantial differences in body composition measurements.

In conclusion, differences in body composition values in various nations can be explained by regional variation in genetic, dietary, and physical activity determinants. Results of this study suggest caution in the use of BMI percentile changes for estimation of adiposity, especially in Iranian boys and particularly in lower BMI. Therefore, it could be suggested that using FMI values for classification of obesity can be considered. Further studies are needed to determine gender and age specific cut-off values of FMI that are valid for the health risk-based definitions of pediatric obesity.

The authors declare no conflict of interest

Acknowledgments

This study was supported by a grant (89-5127) from the Shiraz University of Medical Sciences. We would like to thank Dr. Nasrin Shokrpour at Center for Development of Clinical Research of the Nemazee Hospital for editorial assistance.

References

1. De Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr*. 2010; **92:** 1257 – 1264.
2. Aronne LJ, Segal KR. Adiposity and fat distribution outcome measures: assessment and clinical implications. *Obes Res.* 2002; **10(S11):** 14S – 21S.
3. Eshraghian A, Dabbaghmanesh MH, Eshraghian H, Fattahi MR, Omrani GR. Nonalcoholic fatty liver disease in a cluster of Iranian population: thyroid status and metabolic risk factors. *Arch Iran Med*. 2013; **16:** 584 – 9. Epub 2013/10/08.
4. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ.* 2000; **6:** 1240 – 1243.
5. Ogden Cl, Kuczmarski RJ, Flegal KM, Mei Z, Guo S, Wei R, et al. Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version. *Pediatrics.* 2002; **109:** 45 – 60.
6. Sweeting HN. Measurement and definitions of obesity in childhood and adolescence: a field guide for the uninitiated. *Nutr J.* 2007; **6:** 32.
7. Neovius M, Rasmussen F. Evaluation of BMI-based classification of adolescent overweight and obesity: choice of percentage body fat cutoffs exerts a large influence. The COMPASS study. *Eur J Clin Nutr.* 2008; **62:** 1201 – 1207.
8. Daniels SR. The use of BMI in the clinical setting. *Pediatrics.* 2009; **124:** S35.
9. Bray GA, DeLany JP, Harsha DW, Volaufova J, Champagne CM. Body composition of African American and white children: a 2□year follow□up of the BAROC study. *Obes Res.* 2001; **9:** 605 – 621.
10. Janssen I, Heymsfield SB, Allison DB, Kotler DP, Ross R. Body mass index and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. *Am J Clin Nutr*. 2002; **75:** 683 – 688.
11. Aeberli I, Gut-Knabenhans M, Kusche-Ammann RS, Molinari L, Zimmermann MB. A composite score combining waist circumference and body mass index more accurately predicts body fat percentage in 6- to 13-year-old children. *Eur J Nutr.* 2013; **52:** 247 – 253.
12. Goran MI, Gower BA. Relation between visceral fat and disease risk in children and adolescents. *Am J Clin Nutr*. 1999; **70:** 149s – 156s.
13. Helba M, Binkovitz LA. Pediatric body composition analysis with dual-energy X-ray absorptiometry. *Pediatr Radiol.* 2009; **39:** 647 – 656.
14. Ogle GD, Allen JR, Humphries I, Lu PW, Briody JN, Morley K, et al. Body-composition assessment by dual-energy x-ray absorptiometry in subjects aged 4–26 y. *Am J Clin Nutr.* 1995; **61:** 746 – 753.
15. Khadilkar A, Sanwalka N, Chiplonkar S, Khadilkar V, Pandit D. Body fat reference percentiles on healthy affluent Indian children and adolescents to screen for adiposity. *Int J Obes*. 2013; **37:** 947 – 953.
16. Van der Sluis I, De Ridder M, Boot A, Krenning E, de Muinck Keizer-Schrama S. Reference data for bone density and body composition measured with dual energy x ray absorptiometry in white children and young adults. *Arch Dis Child*. 2002; **87:** 341 – 347.
17. Sala A, Webber CE, Morrison J, Beaumont LF, Barr RD. Whole-body bone mineral content, lean body mass, and fat mass measured by dual-energy X-ray absorptiometry in a population of normal Canadian children and adolescents. *Can Assoc Radiol J*. 2007; **58:** 46 – 52.
18. Ayatollahi SM. Obesity in school children and their parents in southern Iran. *Int J Obes Relat Metab Disord*. 1992; **16:** 845 – 850
19. Kelishadi R, Haghdoost AA, Sadeghirad B, Khajehkazemi R. Trend in the prevalence of obesity and overweight among Iranian children and adolescents: A systematic review and meta-analysis. *Nutrition*. 2014; **30:** 393 – 400.
20. Mohammadpour-Ahranjani B, Rashidi A, Karandish M, Eshraghian MR, Kalantari N. Prevalence of overweight and obesity in adolescent Tehrani students, 2000-2001: an epidemic health problem. *Public Health Nutr*. 2004; **7:** 645 – 648.
21. Rahmanian M, Kelishadi R, Qorbani M, Motlagh ME, Shafiee G, Aminaee T, et al. Dual burden of body weight among Iranian children and adolescents in 2003 and 2010: the CASPIAN-III study. *Arch Med Sci*. 2014; **10:** 96 – 103.
22. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR. American College of Sports Medicine Position Stand: physical activity and bone health. *Med Sci Sports Exerc*. 2004; **36:** 1985 – 1996.
23. Jeddi M, Roosta MJ, Dabbaghmanesh MH, Omrani GR, Ayatollahi SMT, Bagheri Z, et al. Normative data and percentile curves of bone mineral density in healthy Iranian children aged 9–18 years. *Arch Osteoporos*. 2013; **8:** 1 – 11.
24. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics.* 2007; **120 (suppl 4):** S164 – S192.
25. Visser M, Fuerst T, Lang T, Salamone L, Harris TB. Validity of fan-beam dual-energy X-ray absorptiometry for measuring fat-free mass and leg muscle mass. *J Appl Physiol.* 1999; **87:** 1513 – 1520.
26. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. *Stat Med.* 1992; **11:** 1305 – 1319.
27. Cole TJ. Fitting smoothed centile curves to reference data. *J R Stat Soc Ser A Stat Soc*. 1988; **151:** 385 – 418.
28. Pan H, Cole TJ. User's guide to lmschartmaker, Medical Research Council, UK; 1997 – 2005.
29. Cleveland WS. Robust locally weighted regression and smoothing scatterplots. *J Am Stat Assoc.* 1979; **74:** 829 – 836.
30. Kim K, Yun SH, Jang MJ, Oh KW. Body fat percentile curves for Korean children and adolescents: a data from the Korea National Health and Nutrition Examination Survey 2009–2010. *J Korean Med Sci.* 2013; **28:** 443 – 449.
31. Demerath EW, Schubert CM, Maynard LM, Sun SS, Chumlea WC, Pickoff A, et al. Do changes in body mass index percentile reflect changes in body composition in children? Data from the Fels Longitudinal Study. *Pediatrics.* 2006; **117:** e487 – e495.
32. Pandit D, Chiplonkar S, Khadilkar A, Khadilkar V, Ekbote V. Body fat percentages by dual-energy X-ray absorptiometry corresponding to body mass index cutoffs for overweight and obesity in Indian children. *Clin Med Pediatr*. 2009; **3:** 55 – 61.
33. Rossen LM. Neighbourhood economic deprivation explains racial/ethnic disparities in overweight and obesity among children and adolescents in the USA. *J Epidemiol Community Health*. 2014; **68:** 123 – 129.
34. Khadgawat R, Marwaha R, Tandon N, Mehan N, Upadhyay A, Sastry A, et al. Reference Intervals of Percentage Body fat in Apparently Healthy North-Indian School Children and Adolescents. *Indian Pediatr*. 2013; **50:** 859 – 866.
35. Ogden CL, Li Y, Freedman D, Borrud L, Flegal K. Smoothed percentage body fat percentiles for US children and adolescents, 1999-2004. *Natl Health Stat Report*. 2011; **9:** 1 – 7.
36. Wells JC, Williams JE, Chomtho S, Darch T, Grijalva-Eternod C, Kennedy K, et al. Body-composition reference data for simple and reference techniques and a 4-component model: a new UK reference child. *Am J Clin Nutr*. 2012; **96:** 1316 – 1326.
37. Ma J, Feng N, Zhang SW, Pan YP, Huang YB. Comparison of changes in body composition during puberty development of obese and normal-weight children in China. *Biomed Environ Sci.* 2009; **22:** 413 – 418.
38. Kurtoglu S, Mazicioglu MM, Ozturk A, Hatipoglu N, Cicek B, Ustunbas HB. Body fat reference curves for healthy Turkish children and adolescents. *Eur J Pediatr*. 2010; **169:** 1329 – 1335.
39. Wells JC. Body composition in childhood: effects of normal growth and disease. *Proc Nutr Soc.* 2003; **62:** 521 – 528.
40. Wang H, Story RE, Venners SA, Wang B, Yang J, Li Z, et al. Patterns and interrelationships of body-fat measures among rural Chinese children aged 6 to 18 years. *Pediatrics*. 2007; **120:** e94 – e101.
41. Garnett SP, Hogler W, Blades B, Baur LA, Peat J, Lee J, et al. Relation

between hormones and body composition, including bone, in prepubertal children. *Am J Clin Nutr*. 2004; **80:** 966 – 972.
42. Loomba-Albrecht LA, Styne DM. Effect of puberty on body composition. *Curr Opin Endocrinol Diabetes Obes*. 2009; **16:** 10 – 15.
43. Steinberger J, Jacobs D, Raatz S, Moran A, Hong C, Sinaiko A. Comparison of body fatness measurements by BMI and skinfolds vs dual energy X-ray absorptiometry and their relation to cardiovascular risk factors in adolescents. *Int J Obes*. 2005; **29:** 1346 – 1352.
44. Cleeman J, Grundy S, Becker D, Clark L. Expert panel on detection, evaluation and treatment of high blood cholesterol in adults. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Adult Treatment Panel (ATP III). *JAMA*. 2001; **285:** 2486 – 2497.
45. Lee S, Bacha F, Gungor N, Arslanian SA. Waist circumference is an independent predictor of insulin resistance in black and white youths. *J Pediatr*. 2006; **148:** 188 – 194.
46. Kelly TL, Wilson KE, Heymsfield SB. Dual energy X-Ray absorptiometry body composition reference values from NHANES. *PLoS One*. 2009; **4:** e7038.