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First body fat reference curves for Macedonian children and adolescents: the MAKFIT study

Primeras curvas de referencia de grasa corporal para niños y adolescentes macedonios: el estudio MAKFIT

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Abstract

Introduction: childhood obesity is a worldwide chief health problem. Along with body mass index, body fat percentile values can also be used to predict future cardiovascular and metabolic health risks.

Objective: the study's aim is to define the percentile values and curves about the fat tissue percentage through which the childhood and adolescent overweight/obesity in the Republic of North Macedonia will be diagnosed.

Methods: the research was conducted on a sample of 15,075 children and adolescents aged six to 14 years (7,627 boys and 7,448 girls). Body fat percentage was established by bioelectrical impedance. The LMS method was used in percentile values and curves' construction.

Results: the boys' 50th percentile curve shows that the body fat percentage average value has a slight growth from seven to ten years of age, but after their 10th it begins to drop continuously until the age of 14 years. At the same time, the girls' body fat percentage average value increases continuously from six to 14 years of age.

Conclusion: since body mass index cannot always establish body fat content, the direct assessment of body fat by bioelectrical impedance would be of great advantage for pediatric and clinical decisions. Therefore, the study provides referent percentile norms for the body fat percentage of healthy Macedonian children and adolescents. For this purpose, a practical and clinically applicable method was used. The obtained referent percentile norms can be useful in assessing overweight and obesity in Macedonian children and adolescents.

Keywords:

Children. Adolescents. Obesity. Body fat percentage. Reference curves.

Resumen

Introducción: la obesidad infantil es un problema importante de salud principal a nivel mundial. Conjuntamente con el índice de masa corporal, los valores percentiles de grasa corporal también se pueden utilizar para predecir futuros riesgos para la salud cardiovascular y metabólica.

Objetivo: el objetivo del estudio es definir los valores percentiles y las curvas sobre el porcentaje de tejido graso, a través de los cuales se diagnosticará sobrepeso u obesidad infantil y adolescente en la República de Macedonia del Norte.

Métodos: el estudio se realizó sobre una muestra de 15.075 niños y adolescentes de seis a 14 años (7.627 niños y 7.448 niñas). El porcentaje de grasa corporal se estableció mediante impedancia bioeléctrica. La construcción de los valores percentiles y las curvas se llevó a cabo mediante el método LMS.

Resultados: la curva del percentil 50 de los niños indica que el valor promedio del porcentaje de grasa corporal tiene un leve crecimiento desde los siete hasta los diez años de edad, pero a partir de los diez comienza a descender continuamente hasta los 14 años. Mientras tanto, el valor promedio del porcentaje de grasa corporal de las niñas aumenta continuamente entre los seis y los 14 años de edad.

Conclusión: teniendo en cuenta que el índice de masa corporal no siempre puede determinar el contenido de grasa corporal, la evaluación directa de la grasa corporal mediante impedancia bioeléctrica podría ser una gran ventaja para las prácticas clínicas y pediátricas. Por lo tanto, este estudio propone normas de referencia para los valores percentiles de porcentaje de grasa corporal de niños y adolescentes macedonios sanos. En este sentido, se utilizó un método práctico y clínicamente aplicable. Finalmente, las normas de referencia obtenidas pueden ser útiles para evaluar el sobrepeso y la obesidad en niños y adolescentes macedonios.

Palabras clave:

Niños. Adolescentes. Obesidad. Porcentaje de grasa corporal. Curvas de referencia.

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INTRODUCTION

Obesity is a metabolic disorder that can be established on grounds of the increased body fat percentage and is considered to be an important risk factor for several diseases (1). The global rates increasing of overweight/obesity has tripled within the last three decades, and this growth is observed in all ages, genders, racial and ethnical groups (2). The prevalence of children and adolescent overweight and obesity in the Republic of North Macedonia varies about 35 % and is somewhat higher in boys than in girls (3-7), and Macedonian children are among the fattest in Europe according to Ortega et al. (8). The lifestyle and social status are among the most significant factors that contribute to obesity. Physical activity and diet habits are the most important lifestyle factors that regulate body energy consumption in preventing and treating obesity (9-11). Body mass index is widely implemented as an indicator in assessing body fat in most research studies where excessive weight gain and obesity are investigated (12).

Since the fat/fat-free ratio varies in people, the relation between height and weight expressed as body mass index is not a suitable indicator of the amount of adipose tissue (13). Along with that, body mass index makes no difference between the excess of fat in relation to the fat-free component (14). Thus, the body fat percentage in obese children cannot be established through body mass index screening only (14). Therefore, it is necessary to have a more accurate assessment of the childhood and adolescent overweight and obesity prevalence and take appropriate measures to reduce it, since it can cause health problems, such as cardiovascular diseases, hypertension, diabetes and asthma, as well as some mental disorders (15).

The percentile normative values and curves creation about the body fat percentage is a highly important approach in monitoring growth, assessing physical health and body fat in children, without leaving out the effect of the diet as well as cultural and social factors. Bioelectrical impedance analysis (BIA) may be a suitable tool for measuring the fat component because it is relatively inexpensive and simple to use. Percentages of body mass that are higher than 85th and 95th are respectively considered as overweight and obesity (16). Despite the importance of adipose tissue regulation for physical well-being in children and adolescents, limited percentile normative values and curves for adipose tissue percentage are available (17), and, to our knowledge, there is quite a small number of research studies in the countries of the Western Balkans and the Republic of North Macedonia in which the adipose tissue percentile values and curves are defined. Therefore, the present study followed the goal to define the acceptable percentile curves for the body fat percentage, through which overweight/obesity will be diagnosed in children and adolescents in the Republic of North Macedonia.

METHODS

SUBJECTS

Officially, the Republic of North Macedonia is divided into eight planning regions (Fig. 1), which serve statistical, economic and administrative purposes. For research purposes, a stratified quota sample was designed from all eight planning regions. For that, official data on students' assessments were used, which were published on the website of the State Statistics Office of the Republic of North Macedonia. Then, respondents in each segment/stratum were calculated and selected on grounds of the specific ratio of quotas according to: gender, ethnicity and place of residence (urban/rural). The research was conducted on a sample of 15,075 respondents, which represent about 9 % of the total population of students from elementary schools in the Republic of North Macedonia. The sample was divided into two subsamples according to the gender, namely 7,627 male and 7,448 female respondents. The total number of children and adolescents was divided into nine groups, according to chronological age (six years, seven years, eight years, nine years, ten years, eleven years, 12 years, 13 years, and 14 years of age). The average age of the respondents of both genders was 9.8 ± 2.4 years.

The study included all students whose parents agreed to participate in the project, who were psychophysically healthy and who regularly attended physical and health education classes. The respondents were treated in accordance with the Declaration of Helsinki (Edinburgh 2013 revision). The protocols were approved by the Ethics Commission at the St. Cyril and Methodius University in Skopje. The research was an integral part of the project "System for continuous and systematic monitoring of physical fitness among students at the national level under the name MAKFIT". The measurements were carried out during the period 2018-2022, in standard school conditions of the regular classes of Physical and Health Education (Fig. 1).

Figure 1.
Map of the statistical and planning regions of the Republic of North Macedonia.

MEASUREMENTS

In order to achieve the objectives of the research, the following anthropometric parameters were measured: height, weight and body fat (fat tissue) percentage. Weight was

measured under standard conditions using a digital scale model BF-511 with a measurement accuracy of 0.1 kg. The measurement was conducted during the morning hours before breakfast, and the respondents were dressed in light clothes. The students' height was measured in a standing position without shoes, using a stadiometer with a precision of 0.1 cm.

The measurement of the percentage of body fat was carried out by the BIA method, which is a safe, simple, fast and relatively inexpensive method for measuring body composition, especially in epidemiological studies (18-20). Percentage body fat was measured by whole-body BIA to the nearest 0.1 % using a digital scale/body composition monitor (Omron BF 511, 50 kHz, 500 μA, Kyoto, Japan), which includes an eight-sensor technology using both hands and feet. The participants stood with bare feet on electrodes on the scale with their knees and back straight while grasping a handle that also includes electrodes with both their hands horizontally raised, elbows extended straight, and maintaining a 90°-angle to the body. A previous study that compared body composition estimates using BIA devices with dual-energy X-ray absorptiometry (DEXA) and whole body magnetic resonance imaging indicated that the use of devices with additional hand electrodes provides a more accurate prediction of body composition and are suitable for public use (21). In order to determine percentage body fat, the device uses electrical impedance, along with the participant's height, weight, age, and gender to generate results. The readings were obtained in duplicates and the average was recorded. According to the manufacturer's instructions, percentage body fat was measured two hours or more after breakfast (22). The measurement was conducted by experts in the field of kinesiology and medicine, who were previously trained to measure a certain anthropometric measure.

STATISTICAL ANALYSIS

The variables' normal distribution was determined by the Kolmogorov-Smirnov test. Basic descriptive statistical parameters (arithmetic mean and standard deviation) were calculated for all variables. Gender differences were determined using Student's t-test for independent samples. One factor analysis of variance and Tukey post hoc tests were used to establish the differences between the arithmetic means of adjacent age groups. A p value of < 0.05 was considered as statistically significant. A construction of the percentile curves is done using the LMS method. The method is based on the assumption that the data have a normal distribution at each level of covariability, where the percentiles for each age category are summed up based on the specificities of age, and previously, by the help of the Box-Cox transformation, the data was normalized (correction of symmetry) if necessary. Percentile normative standards and curves were generated using the LMSChart Maker Pro version 2.3 software package (The Institute of Child Health, London). The following percentiles normative standards were calculated: $P3^{th}$, $P5^{th}$, $P10^{th}$, $P25^{th}$, $P50^{th}$, $P75^{th}$, $P90^{th}$, $P95^{th}$ and $P98^{th}$. All comparisons were performed using SPSS 26.0 for Windows (IBM Corporation, New York, NY, United States).

RESULTS

The research was conducted on a sample of 15,075 children and adolescents (7,627 [50.6 %] boys and 7,448 [49.4 %] girls) aged six to 14, from eight regions of the Republic of North Macedonia. Boys had a statistically significantly higher body fat percentage between ages six and eight, while girls had a statistically significantly higher body fat percentage between the ages of 12 and 14. Statistically significant differences in the fat tissue percentage between boys and girls were not determined at nine, ten and eleven years of age (Table I).

Table I. Mean (SD) percentage of body fat for Macedonian children and adolescents aged 6-14 years and comparisons of the means

Age	Boys			Girls			t-value	*p*-value
	n	Mean	SD	*n*	Mean	SD		
6 years	614	23.73	7.05	725	21.03	7.85	6.62	< 0.001
7 years	805	22.96	7.46	808	21.96	7.91	2.61	0.009
8 years	1085	23.05	8.03	1072	22.06	8.38	2.80	0.005
9 years	1050	23.94	7.92	1011	23.39	8.68	1.50	0.134
10 years	1026	24.22	8.17	934	23.52	8.56	1.84	0.065
11 years	889	23.28	8.49	821	23.26	8.25	0.05	0.962
12 years	756	21.79	8.47	738	24.18	7.91	-5.64	< 0.001
13 years	753	19.97	8.46	725	25.87	7.45	-14.24	< 0.001
14 years	649	18.44	7.77	614	27.26	6.71	-21.60	< 0.001

From the analysis of table I, it can be seen that the adipose tissue percentage shows oscillatory changes with the age increasing in both sexes. With the boys, body fat marks the highest percentage of increase between the 8th and 9th year; on average scale it is 0.88 %. With the girls, the greatest percentage increase in body fat is shown between the 12th and 13th year, which is by 1.69 % on average. With the boys from the 10th to the 14th year, there is a trend of decreasing the body fat percentage from year to year. With the girls between the ages of ten and eleven, the fat tissue percentage reduction occurs by 0.26 % on average, and after that it comes to a continuous increase of the body fat percentage until the age of 14. The fat tissue percentage shows the greatest variability for boys in their 13th year, while for girls it occurs in the 8th year. The lowest variability adipose tissue percentage with the boys is marked in the 6th year, while in girls in the 14th year.

From the values of the Tukey post hoc test, which was applied to establish the differences between the adjacent-age groups' arithmetic means, it can be stated that significant statistical differences have been established with the girls: between eight- and nine-year-old adjacent-age groups, when there is an increase in the fat tissue percentage by about 1.33 % on average; between the 12- and 13-year-old adjacent-age groups, when there is an increase in the body fat percentage by approximately 1.69 %; and in the 13-and 14-year-old adjacent-age groups, in which there is an increase in the fat tissue percentage by about 1.38 % on average. With the boys, significant statistical differences are determined: between the eleven- and 12-year-old adjacent-age groups, when a decrease in the body fat percentage occurs by 1.49 %; between 12- and 13-year-old adjacent age groups, when there is a decrease in the body fat percentage by 1.82 %; and between the 13- and 14-year adjacent-age groups, when the fat tissue percentage decreases by 1.53 %. No significant statistical differences were determined between the other adjacent-age groups and between the two genders (Table II).

Table II. Percentage body fat in percentiles according to age and sex in the boys and girls in this study

Age (years)				Body fat percentage (%)									
	L	M	S	3p	5p	10p	25p	50p	75p	85p	90p	95p	97p
Boys													
6	0.7	23.2	0.3	10.8	12.2	14.5	18.5	23.2	28.2	30.9	32.9	35.8	37.7
7	0.7	22.9	0.3	10.2	11.7	13.9	18.0	22.9	28.0	30.9	32.9	35.9	38.0
8	0.7	23.0	0.3	9.9	11.4	13.7	17.9	23.0	28.4	31.4	33.5	36.7	38.9
9	0.7	23.3	0.4	9.8	11.2	13.7	18.0	23.3	29.0	32.3	34.5	37.9	40.2
10	0.6	23.3	0.4	9.4	10.9	13.4	17.8	23.3	29.3	32.7	35.1	38.7	41.2
11	0.6	22.5	0.4	8.8	10.3	12.6	17.0	22.5	28.6	32.1	34.6	38.4	41.0
12	0.5	21.1	0.4	8.0	9.3	11.5	15.7	21.1	27.1	30.7	33.2	37.1	39.7
13	0.5	19.3	0.4	7.1	8.3	10.3	14.2	19.3	25.2	28.7	31.2	35.1	37.8
14	0.4	17.4	0.4	6.2	7.3	9.1	12.7	17.4	23.1	26.6	29.1	33.0	35.7
Girls													
6	0.5	20.2	0.4	8.2	9.4	11.4	15.3	20.2	25.9	29.3	31.7	35.5	38.1
7	0.5	21.0	0.4	8.3	9.6	11.8	15.8	21.0	26.8	30.3	32.7	36.5	39.0
8	0.6	21.7	0.4	8.4	9.8	12.1	16.4	21.7	27.7	31.1	33.6	37.3	39.8
9	0.7	22.5	0.4	8.6	10.1	12.5	17.0	22.5	28.5	32.0	34.4	38.1	40.5
10	0.7	22.9	0.4	8.9	10.4	12.9	17.5	22.9	28.9	32.2	34.5	38.1	40.4
11	0.7	23.3	0.4	9.5	11.0	13.5	18.0	23.3	28.9	32.1	34.3	37.7	39.9
12	0.7	24.1	0.3	10.7	12.2	14.6	19.0	24.1	29.5	32.5	34.6	37.8	39.9
13	0.8	25.4	0.3	12.4	13.9	16.3	20.5	25.4	30.6	33.5	35.5	38.4	40.4
14	0.8	26.9	0.3	14.6	16.0	18.3	22.3	26.9	31.7	34.4	36.3	39.1	40.9

With the boys, the 50th percentile curve shows that the average value of the body fat percentage increases slightly from the age of 7-10 years, and after the 10th year it starts to decrease continuously until the 14th year, whereas the girls' average value of the body fat percentage continuously increases from the 6th to the 14th year. The boys' 5th percentile curve shows a continuous decrease from six to 14 years of age, which is especially pronounced after the 10th year. On the contrary, the girls' 5th percentile curve shows a continuous increase from the 6th to the 14th year, which is especially pronounced after the 11th year. The 95th percentile curve for boys shows an increase from six to ten years, then a decrease from eleven to 14 years. The 95th percentile curve for girls shows a slight increase from six to ten years, then a decrease at eleven years, and a slight increase again from 12 to 14 years (Fig. 2).

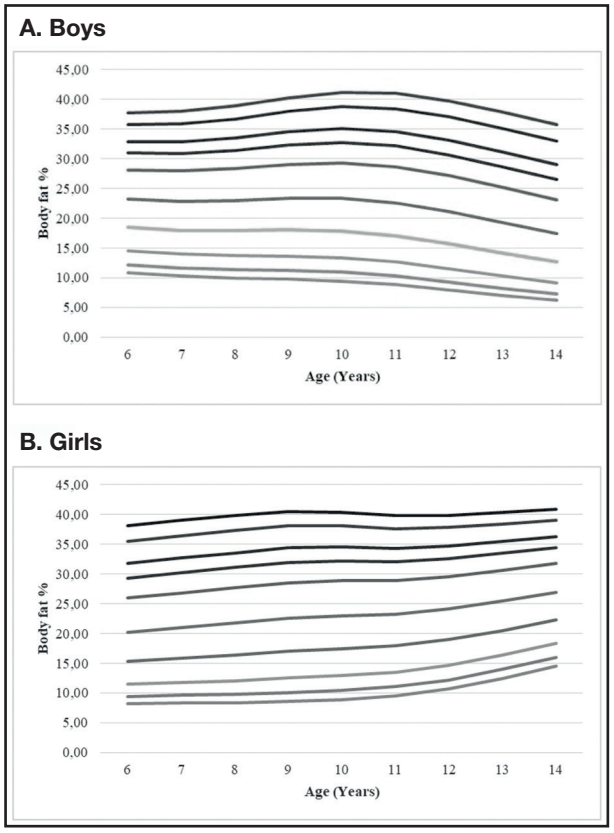

Figure 2.

Percentile curves for percentage body fat of boys (A) and girls (B).

The 50th percentile curves for the adipose tissue percentage in our study were compared to percentile curves from studies conducted in Thailand, Portugal, Turkish, Germany, United Kingdom, United States and the North of Iran. The percentile curves' comparison of the body fat percentage obtained in different studies that have been conducted in various countries should be considered with a great precaution, since the majority of these studies (except for the one performed in the North of Iran) have used different models of BIA, which is very probable to have impacted the results. With the boys, the 50th percentile body fat percentage curve was significantly higher at the ages of six to 13 in comparison with studies conducted in other countries. With the girls, the adipose tissue curve at the 50th percentile was similar to the curves of children and adolescents from Turkey and the United Kingdom, lower than children and adolescents from Portugal, and higher than children and adolescents from the United States, Thailand and Germany. In addition, the patterns of all percentile curves of the fat tissue percentage in the girls from Macedonia were similar to the curves of girls from other countries (Fig. 3).

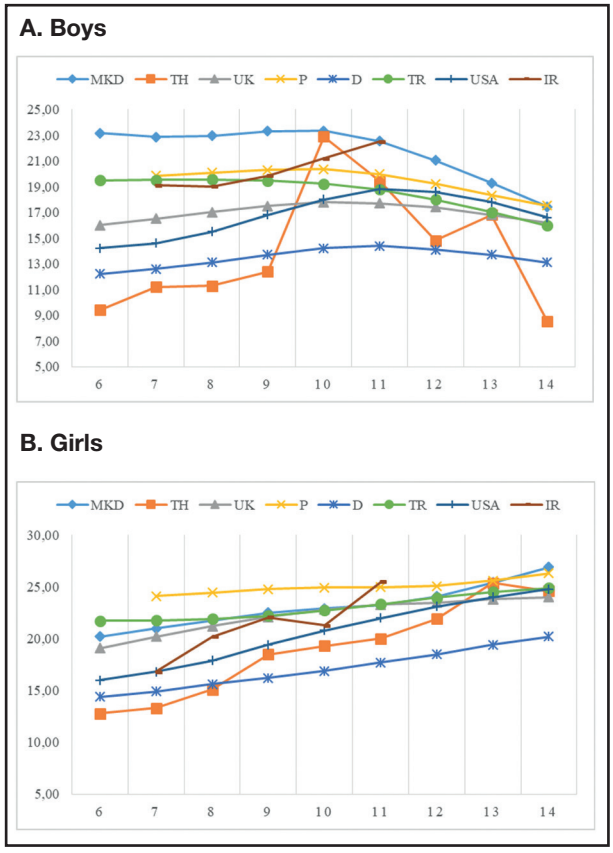

Figure 3.

Comparison of the 50th percentile curves. MKD: North Macedonia; TH: Thailand; UK: United Kingdom; P: Portugal; D: Germany; TR: Turkey; USA: United States; IR: North of Iran.

DISCUSSION

Certain anthropometric measures (such as upper arm circumference, waist circumference and neck circumference) can be used to assess the distribution of body fat in the central and peripheral body parts (7,23-25). DEXA is the most valid method for assessing body fat content and distribution, but it is an expensive and uneconomical method for both epidemiological studies and clinical practice (26). The other two commonly used methods for determining the body fat content and distribution are skinfold thickness and BIA (27,28).

This is the first study in which the normative percentile values and a curve for the body fat percentage have been constructed and measured with BIA for a large sample of Macedonian children and adolescents aged six to 14. The results of the research showed that the average values of the fat tissue percentage are not similar between the boys and girls from Macedonia. In boys, the 50th percentile curve shows that the average value of the adipose tissue percentage increases slightly between the ages of seven and ten, so that after the age of ten it starts to decrease continuously until the age of 14, whereas the average value of the fat tissue percentage in girls increases continuously from the 6th to the 14th year.

Williams et al. provide a cut-off for total percentage of body fat as 30 % for females and 25 % for males as these cut-offs have been significantly associated with cardiovascular risk factors in children and adolescents (29). McCarthy recommends that a body fat percentage between the 85th and 95th percentile is considered to have an excess body fat percentage and above the 95th percentile the respondent is considered to be obese (30). The value obtained from the BIA above the 85th percentile can be considered to mark that the respondent has an excessive body fat percentage (31). In a study published by McCarthy et al., the 85th and 95th body fat percentile values were defined as the cut-off values of excess fat and obesity (30). Their explanation was based on the similarity of percentile curves of body fat percentage (85th and 95th) to percentile curves of body mass index, which are defined by the International Obesity Task Force (30). No consensus has been reached on the diagnosis of obesity based on body fat percentage values (27,28,32). A certain number of studies, which define obesity using BIA, consider that by determining the body fat percentage they would provide additional and useful information for the assessment of obesity in children and adolescents.

In those cases, where body mass index values are within normal values but the body fat content measured by the BIA method shows higher or normal values, the BIA would provide significantly important additional information. On the contrary, a high body mass index does not indicate a high body fat percentage or a disorder of body fat distribution (33). In both cases, the BIA method can be a reliable alternative method that would be used in routine clinical practice (32).

For American girls, the curve for body fat percentage increases continuously with age, while for boys, the body fat percentage increases from age five to eleven, and after age eleven it begins to decrease continuously until the age of 14 (17). In German children aged 3-18, similar to our study, the curve of the fat tissue percentage in girls increases continuously with age, whereas in boys it increases from five to eleven years and then gradually decreases (21). In addition, a study of Turkish children showed that the curve for the body fat percentage in boys increased from seven to ten years of age and then decreased from the age of ten until age 14, while the curve for girls shows continuous increases at a constant rate until the age of 14 (34). In Thai boys, the curve for the body fat percent at the 50th and lower percentiles increases slowly until the age of 12, then decreases slightly until age 15, and then increases again until age 18. In girls, percentile curves for body fat percentage increase steadily from six to 18 years (35). In Portuguese children and adolescents, the body fat percentage increases with age (7-17 years) only in girls (4 %); in boys there is a slight decrease of 3 %. Girls show higher median body fat percentage values than boys at all ages and percentiles, with the exception of the 97th percentile, where eight- to 12-year-old boys have about 0.6-3 % higher body fat percentage than girls at same age (36).

In Chinese children aged 6-18 years, the body fat percentage curve is constant in boys in all age groups, while it shows an increasing trend in girls (37). Kim et al. found in their research that the developmental changes in the curve of the fat tissue percentage differed between Korean boys and girls, with the percentage of the fat component showing a trend of decrease in boys and a gradual increase with age in girls (38). The results of our study showed that the average body fat percentage in boys was statistically significantly higher at ages six to eight, while girls had a statistically significantly higher body fat percentage at the ages 12 to 14 years.

Borrud et al. found that the pattern of body fat distribution differed between American boys and girls, with a higher percentage of body fat in girls than in boys in most age groups, increasing steadily with age in girls (39). The research results in Babol, north of Iran, showed that the body fat average values differ between boys and girls. The 50th percentile curve was slightly higher in boys aged 7-11, and having the highest fat percentage of 22.5 % at the age of eleven years; whereas the fat average percentage in girls aged 7-9 increases with age (16.8-22.05 %), having a slight decrease at the age of nine years, and then reaching the peak of 25.5 % at the age of eleven years (40).

The present study provides first percentile reference values and curves that can be used for the clinical assessment of obesity in Macedonian children and adolescents and provides data for comparison to other countries. The differences in the shape of the percentile curves for the adipose tissue percentage between different countries are due to genetic factors, lifestyle habits, ethnicity, different sampling methods and the BIA model used, among other unknown factors (37).

CONCLUSION

Based on the obtained results, it can be concluded that in this research the first reference percentile curves for the body fat percentage about Macedonian children and adolescents were defined, where in boys they were significantly higher in comparison with those of children and adolescents from other countries. The obtained results for the percentile reference values and curves can help medical and other health advisors to identify and prevent pediatric obesity and reduce the risk of health problems later in life. However, more clinical correlation studies are needed before reliable advice can be offered concerning the percentage of body fat that is meaningful in relation to cardiovascular disease.

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