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Trabajo Original

Pediatría

Reference values of fat mass index and fat-free mass index in healthy Spanish adolescents

Valores de referencia del índice de masa grasa y el índice de masa libre de grasa en adolescentes españoles sanos

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Abstract

Introduction: body mass index (BMI) does not allow to discriminate the composition of the different body compartments. The aim of this study was to develop reference values for the fat mass index (FMI) and fat-free mass index (FFMI) in healthy adolescents using anthropometric techniques in order to provide reference standards for daily clinical practice.

Methods: a cross-sectional study in 1,040 healthy Caucasian adolescents (470 boys and 570 girls) aged 10.1 to 14.9 years. Weight, height, and skinfold thickness were recorded, and BMI, percentage of total body fat, FMI and FFMI, and FMI and FFMI percentiles were calculated.

Results: FFMI and FMI percentiles for healthy adolescents (both sexes) categorized by age are displayed. In boys a significant increase in FFMI is observed, and both the percentage of total body fat and FMI significantly decreased. In contrast, in girls the percentage of body fat mass, FMI, and FFMI significantly increased. Except at 10 years of age, FMI was higher ($p < 0.05$) in girls at all ages. FFMI was higher ($p < 0.05$) in boys at all ages.

Conclusions: reference values of FMI and FFMI would be a very useful instrument in clinical practice for the diagnosis and, especially, the analysis of body composition changes during the treatment of childhood obesity.

Keywords:

Adolescents. Anthropometric measurements. Body composition. Fat mass index. Fat-free mass index. Skinfold thickness.

Resumen

Introducción: el índice de masa corporal (IMC) no permite discriminar la composición proporcional de los distintos compartimentos corporales. El objetivo de este estudio fue elaborar tablas del índice de masa grasa (IMG) y de masa libre de grasa (IMLG) a partir de la medida de los pliegues cutáneos, para que sirvan como patrones de referencia de los adolescentes sanos de ambos sexos.

Material y métodos: estudio transversal de 1040 adolescentes caucásicos sanos (470 varones y 570 mujeres) de entre 10,1 y 14,9 años de edad. Se registraron el peso, la talla y el grosor del pliegue cutáneo, y se calcularon el IMC, el porcentaje de grasa total, el IMG, el IMLG y los percentiles del IMG e IMLG.

Resultados: se exponen los valores medios del IMG y el IMLG con su distribución percentilada en ambos sexos. En los varones aparece un incremento ($p < 0,05$) del IMLG con la edad, mientras que el porcentaje de grasa total y el IMG desminuyen ($p < 0,05$). En cambio, en las mujeres, el porcentaje de grasa total, el IMG y el IMLG se incrementan ($p < 0,05$) con la edad. Salvo a la edad de 10 años, el IMG fue superior ($p < 0,05$) en las mujeres de todas las edades, mientras que el IMLG fue superior ($p < 0,05$) en los varones de todas las edades.

Conclusión: los valores de referencia del IMG y el IMLG podrían ser un instrumento útil en la práctica clínica para el diagnóstico y, especialmente, el análisis de los cambios de la composición corporal durante el tratamiento de la obesidad infantil.

Palabras clave:

Adolescentes. Medidas antropométricas. Composición corporal. Índice de masa grasa. Índice de masa libre de grasa. Espesor del pliegue cutáneo.

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INTRODUCTION

Excess body weight (overweight and obesity) in children has been steadily increasing in industrialized countries, and currently represents the most relevant nutritional disorder (1). The prevalence of excess body weight in the adolescent population in our environment (Navarre, Spain) reaches 22.5 % (2). This rate is practically similar to that of the rest of the Spanish regions, European countries, and US, being superior to that of Eastern European countries (1,3).

Obesity is characterised by an excess in body fat, and body mass index (BMI) is the most usual anthropometric measurement for nutritional assessment in daily clinical practice. As a consequence, it is widely used for the diagnosis of childhood obesity (4). However, BMI does not allow to discriminate the proportional composition of the different body compartments: fat mass and fat-free mass (5-8). In fact, several authors advocate the use of fat mass index (FMI) in contrast to BMI for the diagnosis and monitoring of childhood obesity because of its higher sensitivity to detect changes in body fat (9-12).

The use of FMI in the diagnosis and monitoring of childhood obesity is not sufficiently widespread, and there are few reference charts for pediatricians (13,14). At present, the anthropometric evaluation, due to its simplicity and low cost, is considered an important step in the monitoring of body composition in the pediatric age, and should occupy a prominent place in this process (10,14-18). In point of fact, it would be very useful to arrange for reference FMI as well as fat-free mass index (FFMI) charts based on the measurement of body skinfolds.

The aim of the present work was to compile standard-value FMI and FFMI charts for the healthy adolescent population (both sexes) based on the measurement of skinfolds in order to make them available as benchmarks in daily clinical practice.

METHODS

PARTICIPANTS

This was a cross-sectional study conducted in a sample of 1,040 healthy Caucasian adolescents (470 boys and 570 girls) aged 10.1 to 14.9 years. These were all students who were enrolled in four public schools located in the city of Pamplona (Navarre, Spain) during the period January-June 2018.

The municipality of Pamplona comprises a total population of 203,382 inhabitants (2018 census, *Instituto de Estadística de Navarra*), of which 9,772 (4.8 %) made up the population of 10.1 to 14.9 years of age in the year 2018. The sample frame considered included these 9,772 adolescents (5,042 boys and 4,680 girls). We applied the worst case estimate approach (0.50), a 95 % confidence level, and a precision of 0.04 in order to calculate sample size, and the result was a required minimum number of participants of 600 individuals.

We handed out 1,451 informed consent forms for the subject families to sign (763 boys and 740 girls). The difference in sex distribution is explained as follows: from the initial 763 boys, 136 boys with overweight/obesity (BMI > 1 SD), 78 were excluded due to ethnic reasons (non-caucasian individuals), 17 were excluded due to other reasons (chronic pathologies, etc.), and 62 did not turn in a properly signed consent form within the given period. The total sum of recruited boys was then 470. The response rate after these exclusions was 88.3 %. From the initial 740 girls, 53 girls were excluded because of overweight/obesity (BMI > 1 SD), 57 owing to ethnic reasons (non-caucasian individuals), 11 because of other reasons (chronic pathologies, etc.), and 49 did not return the consent forms in time. The total sum of recruited girls was 570. The response rate after the exclusions was 92.1 %. The overall response rate (both sexes) after the exclusions was 90.4 %.

The normality of nutrition status was the condition for inclusion in this study; this means that BMI had to range between +1 and -1 SDs. In addition, non-Caucasian adolescents and those diagnosed with chronic pathologies that might affect growth, body composition, food ingestion, or physical activity were excluded.

Parents and/or legal guardians were informed and provided their written consent for participation in this study in all cases. This study was approved by the Ethics Committee for Human Investigation at Complejo Hospitalario de Navarra (in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and later amendments).

ANTHROPOMETRIC MEASUREMENTS

The following anthropometric measurements were recorded: weight, height, body mass index (BMI), and skinfold thickness (biceps, triceps, subscapular, and suprailiac).

Weight and height measurements were taken with participants in underwear and barefoot. An Año-Sayol scale was used for weight measurement (reading interval, 0 to 120 kg with a precision of 100 g), and a Holtain wall stadiometer for height measurement (reading interval, 60 to 210 cm, precision 0.1 cm). BMI was calculated according to the following formula: weight (kg) / height^2 (m).

Skinfold thickness measurements were performed in triplicate at the biceps (front side of middle upper arm), triceps (back side of middle upper arm), subscapular (under the lowest point of the shoulder blade), and suprailiac (above the upper bone of the hip) sites; the mean value of these 3 measurements was used, and the measurements were performed by the same individual, who had been trained in skinfold measurement techniques. Skinfold thickness values were measured to a precision of 0.1 mm on the left side of the body using Holtain skinfold calipers (CMS Weighing Equipment, Crymych, United Kingdom). The percentage of total body fat, fat mass (kg) and fat-free mass (kg) were calculated using the equations reported by Slaughter et al. (19), adjusted for sex and age. In the same way, the fat mass index (FMI) and fat-free mass index (FFMI) were estimated using the following formulas: fat mass (kg) / height^2 (m), and fat-free mass (kg) / height^2 (m), respectively.

The z-score values for BMI were computed using the program *Aplicación Nutricional*, developed by Spanish Society for Pediatric Gastroenterology, Hepatology and Nutrition, and available at http://www.gastroinf.es/nutritional/. The graphics by Ferrández et al.

(Centro Andrea Prader, Zaragoza, 2002) were used as reference charts (20).

STATISTICAL ANALYSIS

Results are expressed as means (M) with their corresponding standard deviations (SD). The statistical analysis (descriptive statistics, percentile calculation, Student's t-test, and analysis of variance) was conducted using the Statistical Packages for the Social Sciences, version 20.0 (SPSS, Chicago, IL, USA). The condition for statistical significance was a p-value < 0.05.

RESULTS

Table I lists and compares the mean values of anthropometric and body composition characteristics according to age in adolescent boys. A significant increase in the mean values of weight, height, BMI, fat mass, fat-free mas and FFMI is observed (p < 0.05). In contrast, the mean values of body fat, skinfold thickness (triceps) and FMI significantly decreased (p < 0.05). There are no significant differences in mean values of BMI z-score and skinfold thickness (biceps, subscapular and suprailiac). Table II shows the percentile distributions of FFMI and FMI of the adolescent boys categorized by age.

Table I. Anthropometric measurements and body composition of adolescent boys (M ± SD)

	10 y (n = 82)	11 y (n = 84)	12 y (n = 112)	13 y (n = 108)	14 y (n = 84)	p-value*
Age (y)	10.4 ± 0.3	11.5 ± 0.2	12.4 ± 0.2	13.4 ± 0.2	14.2 ± 0.1	0.001
Weight (kg)	37.9 ± 6.1	39.8 ± 5.5	43.2 ± 7.6	49.3 ± 7.8	54.1 ± 9.1	0.001
Height (cm)	142.0 ± 9.7	146.5 ± 8.2	153.4 ± 9.5	158.7 ± 9.6	164.8 ± 9.4	0.001
BMI (kg/m^2)	18.7 ± 1.5	18.9 ± 1.5	19.2 ± 1.5	19.6 ± 1.6	20.3 ± 1.7	0.001
BMI z-score	0.08 ± 0.61	0.02 ± 0.56	0.01 ± 0.54	0.05 ± 0.57	0.05 ± 0.05	0.072
Skinfold thickness						
Biceps (cm)	9.1 ± 3.5	8.9 ± 2.9	9.1 ± 3.8	8.3 ± 4.2	8.9 ± 4.1	0.508
Triceps (cm)	14.2 ± 3.7	14.5 ± 4.1	13.9 ± 5.1	13.4 ± 5.2	13.5 ± 4.9	0.028
Subscapular (cm)	9.9 ± 4.1	9.8 ± 4.3	10.3 ± 5.1	10.2 ± 5.3	10.2 ± 3.9	0.222
Suprailiac (cm)	12.3 ± 6.3	12.4 ± 6.5	12.2 ± 6.1	12.6 ± 6.8	12.4 ± 6.4	0.328
Body fat (%)	25.4 ± 5.8	24.4 ± 4.5	23.1 ± 5.9	21.5 ± 5.9	22.4 ± 5.9	0.001
Fat mass (kg)	9.7 ± 3.1	9.7 ± 2.9	10.1 ± 3.8	10.2 ± 3.7	11.9 ± 4.1	0.001
Fat-free mass (kg)	28.2 ± 4.3	28.7 ± 4.1	32.7 ± 5.6	37.1 ± 5.8	39.8 ± 6.1	0.001
FMI (kg/m^2)	4.8 ± 1.4	4.6 ± 1.2	4.4 ± 1.4	4.2 ± 1.4	4.3 ± 1.5	0.003
FFMI (kg/m^2)	13.8 ± 0.7	14.2 ± 0.9	14.7 ± 0.9	15.3 ± 0.9	15.6 ± 0.7	0.001

**ANOVA; BMI: body mass index; FMI: fat mass index; FFMI: fat-free mass index.*

Table II. Percentile values for fat mass index and fat-free mass index in adolescent boys at different ages

Fat mass index (kg/m^2)							
Age	**p3**	**p10**	**p25**	**p50**	**p75**	**p90**	**p97**
10 y	2.78	2.85	3.79	4.29	6.25	7.32	7.45
11 y	2.47	2.86	3.58	4.22	5.91	6.93	7.45
12 y	2.17	2.90	3.38	4.15	5.57	6.54	7.46
13 y	2.15	2.48	3.09	4.10	5.56	6.52	6.81
14 y	2.21	2.38	3.07	4.61	5.82	6.76	6.95
Fat-free mass index (kg/m^2)							
Age	**p 3**	**p10**	**p25**	**p50**	**p75**	**p90**	**p97**
10 y	12.25	12.90	13.45	13.93	14.28	14.8	15.12
11 y	12.75	13.10	13.74	14.39	14.86	15.57	15.85
12 y	13.28	13.33	13.96	14.84	15.41	16.35	16.61
13 y	13.38	14.27	14.61	15.32	15.81	17.11	17.85
14 y	14.35	14.81	15.31	15.51	16.17	16.91	17.44

p: percentile.

Table III shows and compares the mean values of anthropometric and body composition characteristics related to age group in adolescent girls. The mean values of weight, height, BMI, skinfold thickness (subescapular and suprailiac), body fat, fat mass, fat-free mass, FMI and FFMI significantly increased ($p < 0.05$). No significant differences in mean values of BMI z-score and skinfold thickness (biceps and triceps) were detected. Table IV displays the percentile distributions of FFMI and FMI of the adolescent girls categorized by age.

Figure 1 lists and presents a comparison of average values for FMI in both sexes at the different ages surveyed. With the exception of the period from 10 to 11 years of age, the FMI value was significantly higher ($p < 0.05$) in girls as compared to boys at all ages.

Figure 2 shows and contrasts the mean values for FFMI in both sexes at the different ages surveyed. FFMI was significantly higher ($p < 0.05$) in boys at all ages.

The comparison of mean BMI values between both sexes at all ages showed no significant differences.

Table III. Anthropometric measurements and body composition of adolescent girls (M ± SD)

	10 y (n = 148)	11 y (n = 108)	12 y (n = 110)	13 y (n = 104)	14 y (n = 100)	p-value*
Age (y)	10.4 ± 0.2	11.5 ± 0.3	12.4 ± 0.3	13.4 ± 0.2	14.3 ± 0.2	0.001
Weight (kg)	38.1 ± 5.3	42.8 ± 6.4	46.0 ± 6.7	49 ± 6.9	52.2 ± 8.1	0.001
Height (cm)	143.0 ± 7.3	149 ± 8.6	154.1 ± 8.5	157.7 ± 8.2	159.8 ± 7.1	0.001
BMI (kg/m^2)	18.6 ± 1.4	19.3 ± 1.6	19.7 ± 1.9	20.1 ± 1.7	20.8 ± 1.9	0.001
BMI z-score	0.09 ± 0.5	0.09 ± 0.53	0.04 ± 0.64	0.05 ± 0.57	0.02 ± 0.67	0.086
Skinfold thickness						
Biceps (cm)	10.3 ± 3.4	10.3 ± 3.9	10.1 ± 2.8	10.4 ± 3.3	10.9 ± 3.2	0.709
Triceps (cm)	16.1 ± 3.9	15.8 ± 4.4	15.9 ± 4.4	16.3 ± 4.5	16.9 ± 3.7	0.738
Subscapular (cm)	10.9 ± 4.2	11.4 ± 4.8	11.1 ± 4.1	12.2 ± 5.2	13.1 ± 5.1	0.002
Suprailiac (cm)	14.4 ± 6.1	15.7 ± 6.5	15.9 ± 6.5	17.7 ± 7.1	18.2 ± 6.4	0.001
Body fat (%)	27.4 ± 5.9	28.3 ± 4.3	28.6 ± 3.7	29.2 ± 4.2	29.3 ± 3.5	0.005
Fat mass (kg)	10.7 ± 3.3	12.5 ± 3.0	13.0 ± 3.1	14.3 ± 2.8	15.6 ± 3.8	0.001
Fat-free mass (kg)	27.7 ± 3.2	31.3 ± 4.4	33.7 ± 4.4	34.7 ± 4.3	37.0 ± 4.4	0.001
FMI (kg/m^2)	5.1 ± 1.4	5.5 ± 1.2	5.7 ± 1.1	5.9 ± 1.2	6.2 ± 1.2	0.001
FFMI (kg/m^2)	13.4 ± 0.8	13.8 ± 0.8	14.2 ± 0.9	14.3 ± 0.9	14.7 ± 0.9	0.001

**ANOVA; BMI: body mass index; FMI: fat mass index; FFMI: fat-free mass index.*

Table IV. Percentile values for fat mass index and fat-free mass index in adolescent girls at different ages

Fat mass index (kg/m^2)							
Age	**p 3**	**p 10**	**p 25**	**p 50**	**p 75**	**p 90**	**p 97**
10 y	2.79	3.46	3.92	5.33	6.24	7.31	7.74
11 y	3.57	3.77	4.68	5.49	6.30	7.21	7.89
12 y	3.75	4.12	4.68	5.18	6.40	7.33	7.88
13 y	3.89	3.99	4.83	5.91	7.07	7.79	7.90
14 y	4.08	4.80	5.02	6.46	6.99	8.28	8.60
Fat-free mass index (kg/m^2)							
Age	**p 3**	**p 10**	**p 25**	**p50**	**p 75**	**p 90**	**p 97**
10 y	12.05	12.31	12.84	13.54	14.04	14.53	14.91
11 y	12.48	12.79	13.17	13.87	14.39	14.86	15.52
12 y	12.86	13.04	13.54	14.29	15.07	15.76	16.31
13 y	12.77	12.78	13.62	14.21	14.45	16.12	16.35
14 y	12.84	13.00	13.87	14.88	15.61	16.00	16.55

p: percentile.

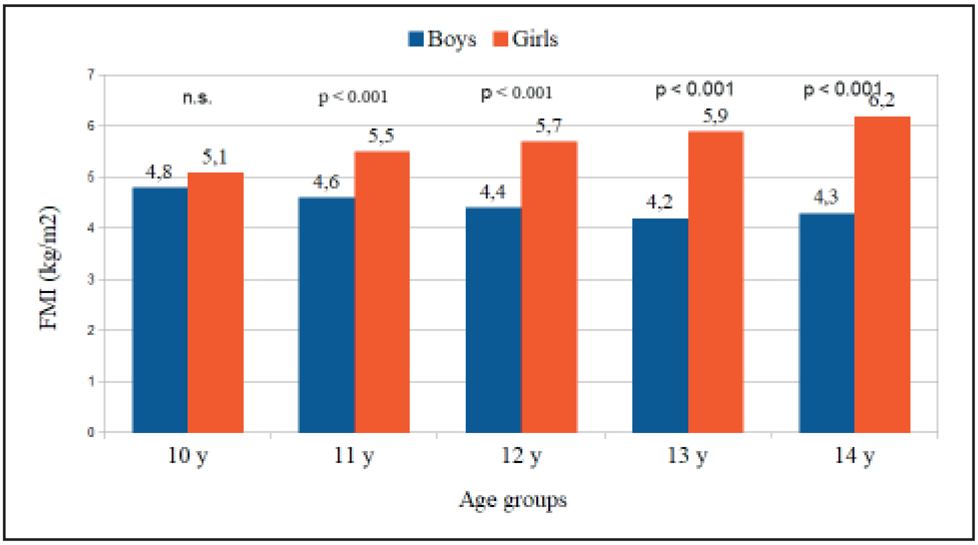

Figure 1.

Gender differences for FMI within age groups.

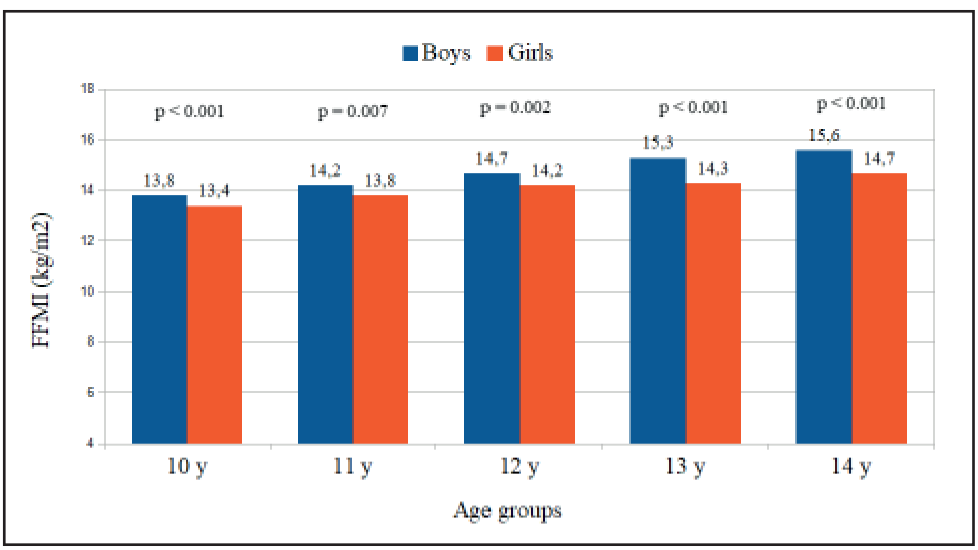

Figure 2.

Gender differences for FFMI within age groups.

DISCUSSION

The analysis of evolutionary changes in the body compartments (fat mass and fat-free mas) of healthy adolescents—between 10 and 14 years of age—with normal age- and sex-adjusted BMI reveals a different pattern in relation to sex. There is a progressive and significant increase in FFMI in both sexes, and boys show significantly higher values than girls; in addition, there is a progressive and significant decrease in FMI in boys, in contrast to a progressive and significant increase in FMI in girls. It should be stressed that these changes take place simultaneously with a progressive increase in BMI in both sexes during this period of life, in the absence of significant differences in BMI values between both sexes at the different ages considered.

In this study, BMI was used for the classification of nutritional status among the children who were included. However, although it may be useful to define overweight and obesity (4,10,21,22), it provides limited information since it denotes excessive weight in relation to height rather than excessive body fat; this means that BMI does not allow to discriminate the relative composition of the different body compartments: fat mass and fat-free mass (5-8,23). This limitation becomes more evident during adolescence, when a series of physiological changes occur (24,25) and an increase in weight might be erroneously identified as excessive fat accumulation (26,27). Therefore, having in place standardized FMI and FFMI vaues for healthy adolescents would allow to distinguish between those individuals that, for example, present with high values of BMI and, simultaneously, show a low FFMI and high FMI (a situation that corresponds with overweight or obesity), and those who also present with high BMI but show a high FFMI and low FMI (a situation that would be identified as muscle hypertrophy, which is quite frequent in adolescent boys).

Few reference charts for FMI and FFMI in the pediatric age have been published to date, and they are usually based on sophisticated methodologies, and poorly accessible in clinical practice, such as dual-energy X-ray absorptiometry or isotope dilution (13,14,28); their use is basically limited to scientific investigation. However, there is ample evidence that the values obtained by using anthropometric measurements correlate extremely well with those collected with these sophisticated and high-cost techniques (10,14-18,29,30); even the simpler models that divide the body into FM and FFM are as valid as those more complex models that subdivide FFM into its different components (water, proteins, minerals) (28).

The main limitation of this study was that the public schools that were selected included the most crowded centers in the city of Pamplona and, of course, they were not located in marginal zones. Private school students were not included, nor were other variables that could, to some extent, condition the results, such as parental education, socioeconomic level, etc. However, the inclusion criteria used to allow participation in the study (BMI between +1 and -1 SD) make it possible to obviate these potential differences. Another possible limitation would be that, since all participants were healthy and presented with normal-range BMI, a normal and progressive pubertal development was assumed. This assumption is reasonable and, in fact, practically all the tables available listing anthropometric variables (weight, height, BMI, etc.), both cross-sectional and longitudinal, that are used in pediatric clinical practice refer exclusively to the chronological age of participants (20,31-35).

The accuracy of skinfold data has been questioned due to its hypothetical operator-dependency. But our experience, consistent with that of other authors, indicates that FMI (assessed by skinfolds) can be used as a good predictor of body fat composition changes in childhood obesity (10,21,36). Bioelectrical impedance analysis (BIA) is an alternative method used for the evaluation of body composition; it is based on the impedance or resistance and reactance values of a small electric current as it spreads through the body water. BIA represents a low-cost, non-invasive method, and has proven to be highly reproducible due to easy equipment operation and scarce evaluator influence. Since a majority of BIA studies are performed in adults, it presents with methodological or standardization issues when making measurements in children, particularly with regard to fasting, hydration, voiding, clothing, skin preparation, and body position (37). Furthermore, probably as a consequence of these methodological issues, BIA might be thought of as a method that currently seems to underestimate fat mass and overestimate fat-free mass in both healthy and obese children (38-40). That is, BIA appears to be a potentially valuable technique, but future studies should focus on its methodological issues to provide definitive guidelines that may facilitate standardization for these measurements in children.

As a conclusion, an easy access to charts (made from skinfold measurements) potentially valid as reference patterns for healthy adolescents of both sexes would be very useful for the diagnosis and, especially, the analysis of body composition changes that may take place during the course of childhood obesity treatment. Certainly, further studies are needed to support these data, as well as to assess their usefulness in clinical practice.

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