

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

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Teodoro Durá-Travé
Universidad de Navarra

✉ tduratra@cfnavarra.es *Corresponding Author*
ORCID: <https://orcid.org/0000-0002-4628-2213>

Fidel Gallinas-Victoriano
Complejo Hospitalario de Navarra

María Chueca-Guindulain
Complejo Hospitalario de Navarra

Sara Berrade-Zubiri
Complejo Hospitalario de Navarra

María Malumbres-Chacón
Complejo Hospitalario de Navarra

Paula Moreno-González
Complejo Hospitalario de Navarra

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KEYWORDS

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

Abstract

Background . Body mass index (BMI) does not allow to discriminate the composition of the different body compartments. The aim of this study is to elaborate reference values of the fat mass index (FMI) and fat-free mass index (FFMI) in healthy adolescents using anthropometric techniques in order to be available as reference standards in daily clinical practice.

Background

Obesity is characterised by an excess of body fat, being body mass index (BMI) 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 [1]. However, BMI does not allow to discriminate the proportional composition of the different body compartments: fat mass and fat-free mass [2-5]. In fact, several authors advocate in the use of the fat mass index (FMI) in contrast to the BMI in order to diagnose and monitor childhood obesity, owing to the higher sensibility to detect changes in body fat [6-9].

The use of FMI in the diagnosis and monitoring of childhood obesity is not sufficiently widespread, and there are few referent charts for pediatricians [10, 11]. 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 [7, 11-15]. In point of fact, it would be very useful to arrange for reference charts of FMI as well as fat-free mass index (FFMI) based on the measurements of body skin folds.

The aim of the present work is to compile standard values charts for FMI and FFMI in healthy adolescents (both sexes), from the measurement of skin folds in order to be available as benchmarks in daily clinical practice.

Materials And Methods

Participants

The municipality of Pamplona comprises a total population of 203 382 inhabitants (2018 census, Instituto de Estadística de Navarra), of which 9772 (4.8%) constituted the population of 10.1 to 14.9 years of age in the year 2018. The sample frame considered included these 9772 adolescents (5042 males and 4680 females). We applied the worst case estimate (0.50), a 95% confidence level and a

precision of 0.04 in order to calculate the sample size, and the result was a minimum number of participants necessary of 600 individuals.

Anthropometric data were collected from a group of 940 healthy Caucasian adolescents (370 men and 570 women), aged 10.1 to 14.9 years. These were all students of the corresponding ages who were enrolled in four public schools located in the city of Pamplona (Navarra, Spain) in the period January-June 2018.

The normality of the nutrition status was the condition sine qua non to be included in this study; this means, BMI should range between +1 and -1 standard deviations (Z-score). In addition, non-Caucasian adolescents and those diagnosed with chronic pathologies that might affect growth, body composition, food ingestion or physical activity were excluded. The response rate after the exclusions was 85.5%.

Anthropometric measurements

The following anthropometric measurements were registered: 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 and 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: $\text{weight (kg)} / \text{height}^2 \text{ (m)}$.

Skinfold-thickness measurements were performed in triplicate at the biceps, triceps, subscapular, and suprailiac sites, and the mean of the 3 values was used, and measurements were performed by the same trained individual. Skinfold thicknesses values were measured to a precision of 0.1 mm on the left side of the body with 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. [16], adjusted for sex and age. In the same way, the fat mass index (FMI) and the fat free mass index (FFMI) were estimated using the following formulas: $\text{fat mass (kg)} / \text{height}^2 \text{ (m)}$, and $\text{free fat mass (kg)} / \text{height}^2 \text{ (m)}$, respectively.

The z-score values for the BMI were computed using the program Aplicación Nutricional, from the Spanish Society of pediatric gastroenterology, hepatology and nutrition (Sociedad Española de Gastroenterología, Hepatología y Nutrición Pediátrica, available at <http://www.gastroinf.es/nutritional/>). The graphics from Ferrández et al. (Centro Andrea Prader, Zaragoza 2002) were used as reference charts [17].

Statistical analysis

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

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

Results

Table 1 lists and compares the mean values of anthropometric and body composition characteristics according to age in adolescents males. A significant increase in the mean values of weight, height, BMI, fat-mass, fat free-mass and FFMI is observed (P<0.05). In contrast, 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 1. Anthropometric measurements and body composition in adolescent males (M + DS).

	10 y (n=62)	11 y (n=64)	12 y (n=92)	13 y (n=88)	14 y (n=64)
Age (y)	10.4±0.3	11.5±0.2	12.4±0.2	13.4±0.2	14.2±.1
Weight (kg)	37.9±6.1	39.8±5.5	43.2±7.6	49.3±7.8	54.1±9.1
Height (cm)	142±9.7	146.5±8.2	153.4±9.5	158.7±9.6	164.8±9.4
BMI (Kg/m ²)	18.7±1.5	18.9±1.5	19.2±1.5	19.6±1.6	20.3±1.7
BMI z-score	0.08±0.61	0.02±0.56	0.01±0.54	0.05±0.57	0.05±0.05
Skinfold thickness					
Biceps (cm)	9.1±3.5	8.9±2.9	9.1±3.8	8.3±4.2	8.9±4.1
Triceps (cm)	14.2±3.7	14.5±4.1	13.9±5.1	13.4±5.2	13.5±4.9
Subscapular (cm)	9.9±4.1	9.8±4.3	10.3±5.1	10.2±5.3	10.2±3.9
Suprailiac (cm)	12.3±6.3	12.4±6.5	12.2±6.1	12.6±6.8	12.4±6.4
Body fat (%)					
Body fat (%)	25.4±5.8	24.4±4.5	23.1±5.9	21.5±5.9	22.4±5.9
Fat mass (kg)	9.7±3.1	9.7±2.9	10.1±3.8	10.2±3.7	11.9±4.1
Fat-free mass (kg)	28.2±4.3	28.7±4.1	32.7±5.6	37.1±5.8	39.8±6.1
FMI (kg/m ²)	4.8±1.4	4.6±1.2	4.4±1.4	4.2±1.4	4.3±1.5
FFMI (kg/m ²)	13.8±0.7	14.2±0.9	14.7±0.9	15.3±0.9	15.6±0.7

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

Table 2 displays the percentiles distributions of FFMI and FMI of adolescents male categorized by age.

Table 2. Percentiles values for fat mass index and fat-free mass index in adolescent males in different ages.

Fat mass index (kg/m ²)						
Age	P 3	P 10	P 25	P 50	P 75	P 90
10 y	2.78	2.85	3.79	4.29	6.25	7.32
11 y	2.47	2.86	3.58	4.22	5.91	6.93
12 y	2.17	2.90	3.38	4.15	5.57	6.54
13 y	2.15	2.48	3.09	4.10	5.56	6.52
14 y	2.21	2.38	3.07	4.61	5.82	6.76
Fat-free mass index (kg/m ²)						
Age	P 3	P 10	P 25	P 50	P 75	P 90
10 y	12.25	12.90	13.45	13.93	14.28	14.8
11 y	12.75	13.10	13.74	14.39	14.86	15.57
12 y	13.28	13.33	13.96	14.84	15.41	16.35
13 y	13.38	14.27	14.61	15.32	15.81	17.11
14 y	14.35	14.81	15.31	15.51	16.17	16.91

P: Percentil

Table 3 shows and compares the mean values of anthropometric and body composition characteristics related to age group in adolescents females. Mean values of weigh, height, BMI, skinfold thickness (subscapular and suprailiac), body fat, fat-mass, fat free-mas, 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 3. Anthropometric measurements and body composition in adolescent females (M + DS).

	10 y	11 y	12 y	13 y	14 y
	(n=148)	(n=108)	(n=110)	(n=104)	(n=100)
Age (y)	10.4±0.2	11.5±0.3	12.4±0.3	13.4±.2	14.3±0.2
Weight (kg)	38.1±5.3	42.8±6.4	46.0±6.7	49±6.9	52.2±8.1
Height (cm)	143±7.3	149±8.6	154.1±8.5	157.7±8.2	159.8±7.1
BMI (Kg/m ²)	18.6±1.4	19.3±1.6	19.7±1.9	20.1±1.7	20.8±1.9
BMI z-score	0.09±0,5	0.09±0,53	0.04±0,64	0.05±0,57	0.02±0,67
Skinfold thickness					
Biceps (cm)	10.3±3.4	10.3±3.9	10.1±2.8	10.4±3.3	10.9±3.2
Triceps (cm)	16.1±3.9	15.8±4.4	15.9±4.4	16.3±4.5	16.9±3.7
Subscapular (cm)	10.9±4.2	11.4±4.8	11.1±4.1	12.2±5.2	13.1±5.1
Suprailiac (cm)	14.4±6.1	15.7±6.5	15.9±6.5	17.7±7.1	18.2±6.4
Body fat (%)	27.4±5.9	28.3±4.3	28.6±3.7	29.2±4.2	29.3±3.5
Fat mass (kg)	10.7±3.3	12.5±3.0	13.0±3.1	14.3±2.8	15.6±3.8
Fat-free mass (kg)	27.7±3.2	31.3±4.4	33.7±4.4	34.7±4.3	37.0±4.4
FMI (kg/m ²)	5.1±1.4	5.5±1.2	5.7±1.1	5.9±1.2	6.2±1.2
FFMI (kg/m ²)	13.4±0.8	13.8±0.8	14.2±0.9	14.3±0.9	14.7±0.9

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

Table 4 displays the percentiles distributions of FFMI and FMI for female adolescents categorized by age.

Table 4. Percentiles values for fat mass index and fat-free mass index in adolescent females in different ages.

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

P: percentil

Figure 1 lists and presents a comparison of average values for FMI in both sexes in the different ages. With the exception of the period 10-11 years, the value of FMI was significantly higher ($p < 0.05$) in females with respect to males in all ages.

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

The comparison of mean values for BMI in both sexes in all ages shows no significant differences.

Discussion

The analysis of the evolutionary changes in the body compartments (fat mass and fat-free mas) in healthy adolescents -between 10 and 14 years of ages- with a normal BMI adjusted for age and sex reveals a different pattern in relation to sex. There is a progressive and significant increase in the FFMI in both sexes, and males show significantly higher values than females; in addition, there is a progressive and significant decrease in the FMI in males, in contrast to the progressive and significant

increase in the FMI in females. It should be stressed that these changes take place simultaneously with a progressive increase in BMI in both sexes in this period of life, in the absence of significant differences of BMI values in both sexes in the different ages considered.

In this study, BMI was applied for the classification of the nutritional status of the children who were included. However, although it may be useful to define overweight and obesity [1, 7, 18, 19], it provides limited information since it denotes excessive weight in relation to height rather than excessive body fat; this means, it does not allow to discriminate the relative composition of the different body compartments: fat mass and fat-free mass [2-5, 20]. This limitation becomes more evident in adolescence, when a series of physiological changes occur [21, 22] and an increase of weight might be erroneously identified as excessive fat accumulation [23, 24]. Therefore, having in place standardized values of FMI and FFMI in 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 that also present with high BMI but show high FFMI and low FMI (a situation that would be identified as muscle hypertrophy, which is quite frequent in adolescent males).

Few reference charts of 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 bioelectrical impedance analysis, dual -energy X-ray absorptiometry or isotope dilution [10, 11, 25]; its use is basically limited to investigation. However, there is ample evidence that the values that have been obtained by using anthropometric measurements correlate extremely well with those collected with these sophisticated and high cost techniques [7, 11-15, 26]; even those more simple models which divide the body in FM and FFM are as valid as those more complex models that subdivide FFM in its different components (water, proteins, minerals) [25].

Conclusions

As a conclusion, having an easy access to charts (made from the measurements of skin folds) that might be valid as referent patterns in healthy adolescents of both sexes would be a very useful instrument in clinical practice for the diagnosis and, especially, the analysis of body changes that

might take place during the treatment of childhood obesity.

List Of Abbreviations

BMI: body mass index

FFMI: fat-free mass index

FMI: fat mass index

Declarations

Ethics and approval and consent to participate.

This study was approved by the Ethics Committee for Human Investigation of the Navarra Hospital Complex, Pamplona, Spain (in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and later amendments). Parents and/or legal guardians were informed and provided consent for the participation in this study in all cases.

Consent for publication.

Not applicable

Availability of data and material.

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests.

The authors declare that they have no competing interests

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Author's contributions. TDT and FGV participated in study design and data analysis, and wrote the first draft of the manuscript. MCG, SBZ, MMC and PMG participated in data collection and analysis. All authors participated in manuscript preparation and approved its final version.

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Not applicable

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Figures

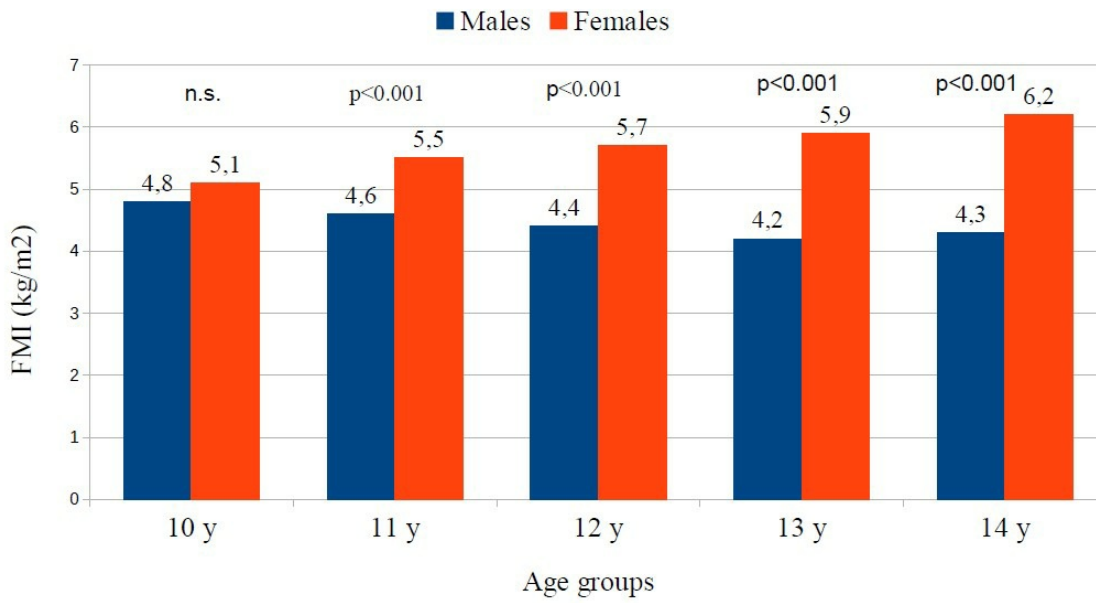


Figure 1

Gender differences for FMI in each of the ages.

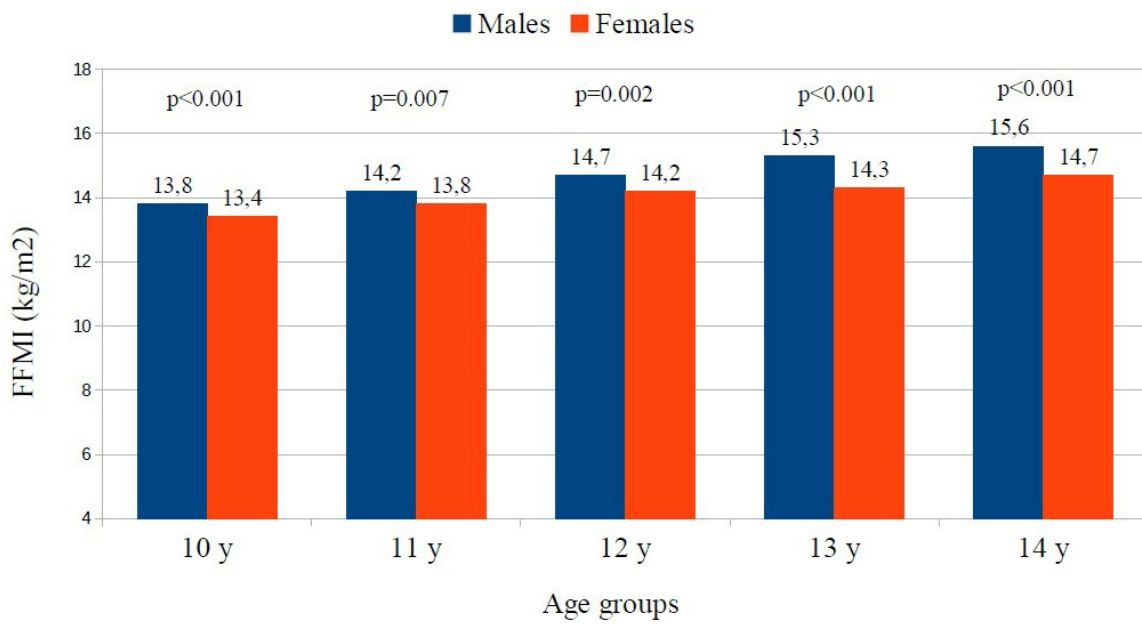


Figure 2

Gender differences for FFMI in each of the ages.