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ORIGINAL ARTICLE

Physical fitness in children and adolescents categorized by fat mass level

Aptitud física en niños y adolescentes categorizados por nivel de masa grasa

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What do we know about the subject matter of this study?

Physical fitness is one of the important health markers as a predictor of cardiovascular disease morbidity and mortality.

What does this study contribute to what is already known?

This study provides important data on the relationship between physical fitness and body composition. Our results indicate that acceptable levels of fat mass are associated with better performance in fitness tests such as standing long jump, agility, and speed in males, and in standing long jump and agility in females.

Abstract

Physical fitness is one of the important health markers as a predictor of cardiovascular disease morbidity and mortality. **Objectives:** To evaluate the relationship between fat mass with anthropometric indicators and, secondly, to compare the performance of physical fitness among children and adolescents categorized with adequate and excess fat mass. **Subjects and Method:** A descriptive cross-sectional study was conducted with 863 schoolchildren aged 6 to 17.9 years. Weight, height, and waist circumference were measured. physical fitness [speed (20m), agility (10x5m), and horizontal jump] was evaluated. Fat mass was calculated by anthropometric equation, body mass index, ponderal index, and waist to height ratio. Data were grouped into 6 age groups. **Results:** Children of both sexes categorized as having adequate levels of fat mass had lower values of body mass index, ponderal index, and waist to height ratio than children with high levels of fat mass. In physical fitness, children with adequate fat mass were better than the ones with elevated fat mass. In girls with adequate fat mass, better results were observed in horizontal jump and agility during

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adolescence. There were no differences in the speed test. **Conclusion:** Fat mass can be considered as a valuable tool for determining excess body fat and categorizing children and adolescents with adequate and excess fat mass. In addition, having acceptable levels of fat mass may contribute to better physical fitness in boys in horizontal jump, agility, and speed and, in girls, only in horizontal jump and agility.

Introduction

In recent years, the interest in studying Physical Fitness (PF) in children and adolescents has significantly increased. Proof of this is that several studies consider PF to be one of the most important health markers, as well as a predictor of morbidity and mortality due to cardiovascular disease (CVD) and other causes[1-3].

PF is modifiable by the reasonable increase of daily physical activity related to occupation, leisure time activity, or through the participation in a structured exercise program[4], allowing to perform at work or any physical or sporting activity efficiently and without excessive fatigue.

In general, during childhood and adolescence, physical, psychological, and social changes occur, which should be timely addressed in order to ensure adequate growth and development. For example, in recent years, children and adolescents spend more time in sedentary activities than a decade ago[6], which leads to a deterioration in health[7], poor physical fitness, childhood and adolescent obesity, and, consequently, an increase in body adiposity[8].

In this context, obesity and overweight are especially worrying problems during childhood and adolescence worldwide[9], especially in Chile since, according to the Ministry of Health, the prevalence of overweight and obesity is 39.8% and 31.2%, respectively[10]. Consequently, it seems that complications related to excess body fat and a sedentary lifestyle represent a major public health problem in several countries, therefore, studying PF performance in children and adolescents with adequate and high levels of fat mass may be relevant, since excess body fat is associated with serious health consequences[11], low levels of PF[12,13], and a significant increase in the risk of premature mortality[14,15].

In essence, understanding the need to maintain adequate levels of fat mass during childhood and adolescence can improve physical performance in the school population, especially in tests such as agility, speed, and standing long jump, given that these motor skills are trained and evaluated regularly in physical education classes.

The objective of the study was to evaluate the relationship between fat mass with anthropometric indicators and to compare the PF performance between children and adolescents categorized with adequate and excess fat mass.

Subjects and Method

Type of study and sample

Cross-sectional descriptive study in schoolchildren from Talca, Chile. The commune of Talca has 31 schools in the urban area, with a population of 16,202 schoolchildren, divided into 8,035 boys and 8,167 girls. The study sample was selected by stratified random sampling, considering age and sex as stratification criteria, resulting in 863 schoolchildren aged between 6 to 17.9 years, 500 males (6.2%) and 363 females (4.5%), representing 10.7% of the total population. All schoolchildren investigated attend public schools, and both children and adolescents attended physical education classes twice a week (the first day 90min/day and the second day 45min/day).

All parents and guardians were invited to a meeting, where they were informed about the study and their doubts were answered. Subsequently, they were asked to sign the informed consent form. The schoolchildren received information on the objectives of the project and signed an informed consent form. The protocols used to measure anthropometry and physical tests were performed according to the suggestions described by the ethics committee of the (UCM-2018) and the Declaration of Helsinki for research on human beings.

Procedures

Data on the date of birth (day, month, and year) were collected from each student's enrollment records and were registered on an index card prepared for this study along with the date of evaluation. The anthropometric and physical fitness evaluations were performed at each school during school hours from 8:30 to 12:30 and 14:30 to 18:00 hours from Monday to Friday between August and October 2019.

Anthropometric measurements were evaluated according to the protocol described by Ross, Marfell-Jones[16]. Body weight (kg) was assessed barefoot, wearing a T-shirt and shorts, using an electronic scale (Tanita, United Kingdom, Ltd.) range of 0-150 kg and

100 g accuracy. Standing height was measured barefoot, according to the Frankfort plane using a portable stadiometer (Seca Gmbh & Co. KG, Hamburg, Germany) with 0.1mm accuracy. Waist circumference (WC) (cm) was measured using a metal tape measure (Seca) graduated in millimeters with 0.1 cm accuracy. All anthropometric variables were measured twice during the same day, with a technical measurement error ranging from 1.0 to 1.4%.

From the anthropometric data collected, Body Mass Index (BMI) [BMI = weight (kg)/height^2 (m)], Ponderal Index (PI) [PI= weight (kg)/height^3 (m)], and Waist-to-Height Ratio (WHtR) [WHtR = Waist circumference (cm)/Height (cm)] were calculated. Fat-free mass (FFM) was estimated by the anthropometric equation proposed by Cossio-Bolaños et al[17] (Boys: FFM = -28.669 + 0.887 * Age + 0.298 * Weight + 0.255 * Height; Girls: FFM = -16.264 + 0.182 * Age + 0.302 * Weight + 0.198 * Height) using the variables age, weight, and height. The equations used presented an R^2 between 0.83 and 0.87% and a standard error of estimate (SEE) between 3.37 and 5.0.

Fat mass (FM) was calculated from (FM = Body weight - FFM), and the %BF from (%FM = (FM*100) / Body weight). To categorize schoolchildren with adequate and excess FM, the cut-off points proposed by Cossio-Bolaños et al.[18] (p10 to p85 adequate and > p85 elevated) were used.

The PF tests were evaluated at each school (gym) after a 10-15min warm-up. Then, the physical tests were performed in the following order: standing long jump (SLJ), 20m sprint test (20m-ST), and 10x5m shuttle run (10x5m-SR).

The SLJ (cm) test evaluates the explosive strength of the lower limbs[19]. A 3 m metal tape measure with 0.1 cm accuracy was used. A baseline was delimited, where the student stood with both feet, with the tip of the toes coinciding with the baseline, to then perform preparatory movements and make a maximum impulse to jump from the baseline forward. The jump was performed three times and the longest distance was recorded.

The 20m-ST was evaluated using a Casio® digital stopwatch (1/100Sec), following Grosser and Starischka[20] procedures. The course was delimited with 3 lines on the floor (each with a cone), a starting baseline, a second line at 20m, and a third line at 25m. Upon the evaluator's signal, the student speeds off from the baseline to complete 25m, with the evaluator positioned at the 20m line to record time. This procedure was performed twice, recording the best time.

In the 10x5m-SR, two lines were marked (5m apart) as described by Verschuren et al[21]. The student had to run at maximum speed from one side to the other, repeating 10 times without stopping (covering 50 meters in total). The time it took to perform the 10 repetitions (sec) was controlled, recording the best time of the two repetitions.

In order to control the quality of the measurements, the SEE was calculated, and the results were between 1.5 and 2.2%. In all cases, these values were highly acceptable.

Statistics

The normality of the data was verified through the Kolmogorov-Smirnov test. Statistical analysis was performed in SPSS 18.0. Descriptive statistics (mean, standard deviation, and range) were calculated. The normal distribution of the variables was confirmed using the Kolmogorov-Smirnov test. Associations between FM and anthropometric indicators were performed using Pearson's correlation coefficient and the coefficient of determination R^2. Comparisons between both sexes were performed using the T-test for independent samples. Six age groups were formed (6 to 7, 8 to 9, 10 to 11, 12 to 13, 14 to 15, 16 to 17 years) and categorized into two groups (adequate and high FM). Comparisons between the adequate and high FM groups were performed by T-test for related samples. In all calculations, $p < 0.05$ was considered.

Results

Table 1 shows the anthropometric variables, body adiposity indicators, and PF test values. Boys presented higher weight and height than girls in most age groups, except for weight between 12 to 13 years and height between 12 and 15 years. In WHtR, boys presented higher values than girls in the group of 15 to 16 years of age. In the other age groups, there were no differences between the sexes. In BMI and WHtR, there were no significant differences between sexes in all age ranges. Regarding FM, girls presented significantly higher values than boys in the groups from 12 to 13 to 16 to 17 years of age ($p < 0.05$). In the FFM, there were no differences in the first age group, however, from 8 to 9 years old to 16 to 17 years old, boys presented significantly higher values in relation to girls.

Regarding the physical tests, in the 20m-ST, there were no differences in the first three age groups (6 to 7, 8 to 9, and 10 to 11 years). When evaluating the results in adolescents, boys were faster than the girls ($p < 0.05$). In SLJ and 10x5m-SR, boys presented lower values in relation to girls in all age groups ($p < 0.05$).

Figure 1 shows the association between FM with anthropometric indicators (BMI, PI, and WHtR). All three indicators showed positive relationships with FM in both sexes. Correlations ranged from 0.63 to 0.96 in boys and from 0.45 to 0.96 in girls. The best relationships were with BMI, followed by PI, and finally with WHtR.

Table 2 shows the comparisons between the categories of adequate and excess FM in children and adolescents of both sexes. The adiposity indices (BMI, PI, and WHtR) were classified according to the levels of FM by age and sex ranges. Significant differences were observed between both categories (adequate FM-excess FM) in all age ranges and both sexes ($p < 0.000$). In general, children of both sexes categorized with adequate levels of FM presented lower values of BMI, PI, and WHtR.

Figure 2 shows the comparisons between children of both sexes categorized with adequate and excess FM. In boys, in the SLJ test, there were no significant differences in the first age group (6 to 7 years), however, in the following age groups, the differences are significant up to 16 and 17 years ($p < 0.05$). Mean differences in children categorized with adequate FM showed better performance from ~5.5 to ~21.8cm compared with those with excess FM.

In the 10x5m-SR test, there were differences in the groups from 8 and 9 years old to 16 and 17 years old ($p < 0.05$). The mean values of children with adequate FM were better in this test compared with those with excess FM (ranging from ~0.9 to ~3.5sec). In the 20m-ST, there were no differences in the group 6 and 7 years, however, in those up to 16 and 17 years, children with adequate FM performed better in this test, with mean values ranging from ~0.3 to ~0.6sec, approximately.

In girls, in the SLJ, no differences were observed in the first three age groups (6 and 7 years, 8 and 9 years, 10 and 11 years), however, in the following groups, the differences were significant in girls categorized with adequate FM who presented better performance than those with excess FM (mean differences ~8.5 to ~11 cm). In the 10x5m-SR test, in the first three age groups, no differences were observed, but in the groups from 12 and 13 years to 16 and 17 years, girls with adequate FM presented better performance than those with excess FM (mean differences ~0.9 to ~5.3sec). In the 20m-ST, no significant differences were observed in all age groups, and the performance was similar in both girls with adequate and excess FM (values ~0.1 to ~0.3sec).

Discussion

Our results show a moderate to a high positive correlation between FM with anthropometric indicators. In addition, children categorized with adequate levels of FM presented lower BMI, PI, and WHtR values compared with those with excess FM. These findings are relevant since the assessment of body composition provides important information on body compartments at the level of adipose, skeletal, and muscular tissue for quantities and distributions according to age and sex[22]. FM can be estimated by measuring abdominal perimeter and waist circumference, both parameters associated with an increased risk of diabetes, heart disease, hyperlipidemia, and overall mortality[23,24]. Also, this indicator could serve as an accurate tool to diagnose and determine excess adipose tissue, as well as in public health surveillance and research.

In fact, in recent years, several studies have confirmed that children and adolescents categorized as having excess body fat are at increased risk of physical performance deterioration, type 2 diabetes mellitus, cancer, and cardiovascular disease in adulthood[25-28]. Excess body fat, generated mainly from caloric energy imbalance[29], complicates the performance of exercise programs due to increased fatigue[30].

From this perspective, highlighting that adequate FM values can bring benefits not only for the general health of children and adolescents but also for preserving better physical fitness, this study proposed, as a second objective, to compare the performance of the PF between children and adolescents categorized as having adequate and excess FM.

Our results suggest that boys with adequate levels of FM presented a better physical performance in SLJ, 10x5m-SR, and 20m-ST, except in the first age group. However, in girls, better physical performance was observed in SLJ and 10x5m-SR during adolescence, while, in the 20m-ST, there were no differences in all age groups.

In general, studies highlight that excess FM is associated with a higher metabolic rate, which makes subjects less efficient in tests requiring lifting and propulsion tasks[31,32], as was observed in this study. However, in girls, there were no differences between both categories (adequate and excess FM) in the 20m-ST. These findings could be because the 20m-ST used in this study does not include the three phases of speed (initial acceleration 0-10m, transition 10-36m, and maximum speed 36-100m)[33] and only covers the first two, so future studies should consider this relevant aspect since it seems that to reach a real maximum speed requires at least 40m.

Essentially, this study allowed us to confirm that children who present adequate levels of FM reflect a better performance of the musculoskeletal system (SLJ) and the motor system (10x5m-SR and 20m-ST), except for girls in 20m-ST.

The results of the study emphasize the importance of promoting exercise programs in overweight and obese children and adolescents[34,35] since this type of intervention is a relevant factor in modifying body composition and can contribute to improving muscle strength levels and physical performance.

Table 1. Anthropometric and physical fitness characteristics of children and adolescents in the sample studied

Ages		Weight (kg)		Height (cm)		WC (cm)		BMI (kg/m2)		PI (kg/m3)		WHtR (a.d)		FM (kg)		FFM (kg)		V-20m (seg)		V-20m (seg)		Agility (seg)	
(years)	n	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Males																							
6 a 7	54	28.6*	6	124.4*	6.9	61.6	8.5	18	2.7	15	2.1	0.50	0.06	11.1	3	17.6	3.7	5.2	0.5	96.8*	20	25.5*	2.8
8 a 9	77	35.7*	8.9	133.1*	7.3	65.2	9.2	20	3.7	15	2.6	0.49	0.06	12.2	5	23.4*	4.5	4.9	0.6	108.4*	24	23.2*	3.4
10 a 11	75	43.4*	11	144	8.5	68.9	10	21	4.1	15	2.7	0.48	0.06	13.2	6.6	30.2*	5.1	4.6	0.5	126.9*	22	21.6*	2.8
12 a 13	38	49.7	11	153	8.4	71.7	8.8	21	3.9	14	2.7	0.47	0.06	13.4*	6.8	36.3*	4.9	4.3*	0.5	143.5*	25	20.5*	2.8
14 a 15	96	64.8*	14	166.6*	7.9	78.8	12	23	4.4	14	2.7	0.47	0.07	18.4*	9.1	46.4*	5.6	3.9*	0.6	164.9*	30	18.4*	2.6
16 a 17	132	71.0*	17	170.6*	5.9	80.7*	13	24	5.3	14	3.1	0.47	0.07	19.9*	12	51.1*	5.9	3.7*	0.6	179.8*	27	17.1*	2
Total	472	53	21	153	19	72.9	13	22	4.8	14	2.8	0.48	0.06	15.7	9	37.3	13	4.3	0.8	144	40	20.3	3.9
Females																							
6-7	59	25.6	6.1	121.6	7.0	60.2	8.3	17.2	3.0	14.1	2.4	0.49	0.06	8.8	3.5	16.7	3.0	5.2	0.9	90.2	20.0	26.5	2.5
8-9	69	33.8	8.5	131.6	7.0	65.8	10.0	19.4	3.7	14.7	2.7	0.50	0.07	12.3	5.1	21.5	3.7	4.6	0.7	101.0	20.8	25.0	2.2
10-11	75	41.1	10.6	143.7	8.6	66.4	9.2	19.7	3.7	13.8	2.6	0.46	0.06	14.6	6.4	26.5	4.5	4.4	0.5	118.2	19.6	23.4	2.8
12-13	45	48.9	10.8	153.4	7.0	70.5	8.9	20.7	4.0	13.5	2.6	0.46	0.06	17.8	6.9	31.1	4.2	4.0	0.7	110.9	18.6	23.2	2.7
14-15	50	62.9	12.9	158.2	6.7	79.5	11.2	25.2	5.2	15.9	3.4	0.50	0.07	26.1	8.7	36.7	4.4	4.2	0.7	119.3	22.5	20.9	4.0
16-17	56	61.1	9.6	159.9	5.9	77.1	7.5	23.8	3.2	14.9	2.1	0.48	0.05	24.2	6.1	36.9	3.7	4.9	0.7	121.2	21.4	18.9	4.8
Total	354	44.3	16.6	143.5	15.6	69.3	11.3	20.8	4.6	14.5	2.7	0.48	0.06	16.7	8.6	27.6	8.4	4.6	0.8	109.9	23.3	23.2	4.0

Legend: X: mean, SD: standard deviation, BMI: body mass index, PI: weight index, WC: waist circumference, WHtR: waist-to-height ratio, FF: fat mass, FFM: fat-free mass, V-20m: speed, HJ: horizontal jump, *: significant difference between men and women.

Table 2. Comparison between adequate and excess body adiposity according to anthropometric indicators

Age (years)	FM (kg)						BMI (kg/m2)				PI (kg/m3)				WHtR (a.d)			
	Adequate			Excess			Adequate		Excess		Adequate		Excess		Adequate		Excess	
	n	X	SD	n	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Males																		
6 a 7	38	9.39*	1.5	16	15.0	1.8	17.0*	1.6	22	1.5	13.9*	1.5	16.9*	1.6	0.47*	0.05	0.54	0.05
8 a 9	61	10.3*	3.3	16	19.6	3.1	18.5*	2.7	25	2.0	14.0*	2.0	18.4*	1.7	0.48*	0.06	0.53	0.06
10 a 11	63	10.8*	3.8	12	25.5	4.5	19.5*	2.6	28	2.6	13.7*	2.0	18.7*	2.1	0.46*	0.05	0.57	0.06
12 a 13	30	10.8*	4.9	8	23.2	2.0	19.5*	2.9	27	2.2	12.8*	1.9	17.0*	2.5	0.45*	0.05	0.53	0.04
14 a 15	62	12.8*	3.4	34	28.7	6.9	20.6*	1.9	28	3.3	12.5*	1.5	16.8*	2.2	0.44*	0.04	0.53	0.06
16 a 17	91	13.8*	4.8	41	33.3	10.9	21.5*	2.4	30	5.0	12.7*	1.5	17.7*	2.9	0.44*	0.04	0.54	0.07
Females																		
6 a 7	55	8.12*	2.3	4	18.5	2.6	16.6*	2.1	25	1.8	13.7*	1.8	19.7*	1.8	0.49*	0.05	0.60	0.04
8 a 9	57	10.5*	3.4	12	20.9	2.2	18.1*	2.8	25	1.7	14.0*	2.2	18.3*	1.9	0.48*	0.06	0.58	0.06
10 a 11	62	12*	2.8	13	26.7	4.8	18.4*	2.2	26	2.2	13.0*	1.9	17.5*	2.1	0.45*	0.05	0.53	0.05
12 a 13	40	16*	4.4	5	32.2	6.8	19.7*	2.5	29	4.1	12.9*	1.7	18.7*	2.7	0.45*	0.05	0.54	0.05
14 a 15	31	20.5*	3.7	19	35.3	6.5	21.9*	2.0	30	4.3	13.9*	1.5	19.3*	3.1	0.46*	0.04	0.57	0.06
16 a 17	48	22.4*	4.3	8	34.9	3.9	22.9*	2.1	29	3.0	14.4*	1.4	18.2*	2.6	0.47*	0.04	0.55	0.05

Legend: X: mean, SD: standard deviation, FM: fat mass, BMI: body mass index, PI: weight index, WHtR: waist-to-height ratio, *: significant difference in relation to the overweight group.

In this sense, it is necessary to plan physical exercises according to individual characteristics, age, and sex[35]. These usually include common activities such as running, jumping, and throwing, which are performed daily through play[36] during physical education classes and in sports initiation programs.

The excess FM and low levels of PF observed in the children and adolescents in this study combined with a sedentary lifestyle are associated with impaired cardiorespiratory function and muscular endurance[37].

In general, the study presents some limitations, since it was not possible to evaluate the participation of the children investigated in sports programs, and the estimation of FM through anthropometry could reflect slight biases in the results of the study, in addition, the cross-sectional study design is limited to describing the results obtained. To confirm our findings, it is relevant that future studies use prospectively followed cohorts. However, this study is one of the first investigations at the national level carried out in a probabilistic sample, covering several age ranges (from 6 to 17 years of age), which allows us to generalize the results to populations with similar characteristics.

Conclusion

From the results obtained in this study, it can be highlighted that the FM can be considered a valuable tool to determine the total body fat excess and to categorize into an adequate and excess level of FM. In addition, presenting acceptable values of FM according to age and sex can contribute to better physical fitness, especially in boys at all ages in SLJ, 10x5m-SR, and 20m-ST and girls only in SLJ and 10x5m-SR during adolescence.

Perspectives and future directions

The improvement of nutritional status and PF may be an important objective in the prevention of chronic diseases[38], as FM may be a determining factor in assessing PF test performance among school children and adolescents[39]. Our results show the need to improve PF, especially in children categorized with excess FM. Further studies evaluating the promotion of exercise programs to prevent obesity in children and adolescents at a national level are needed[40].

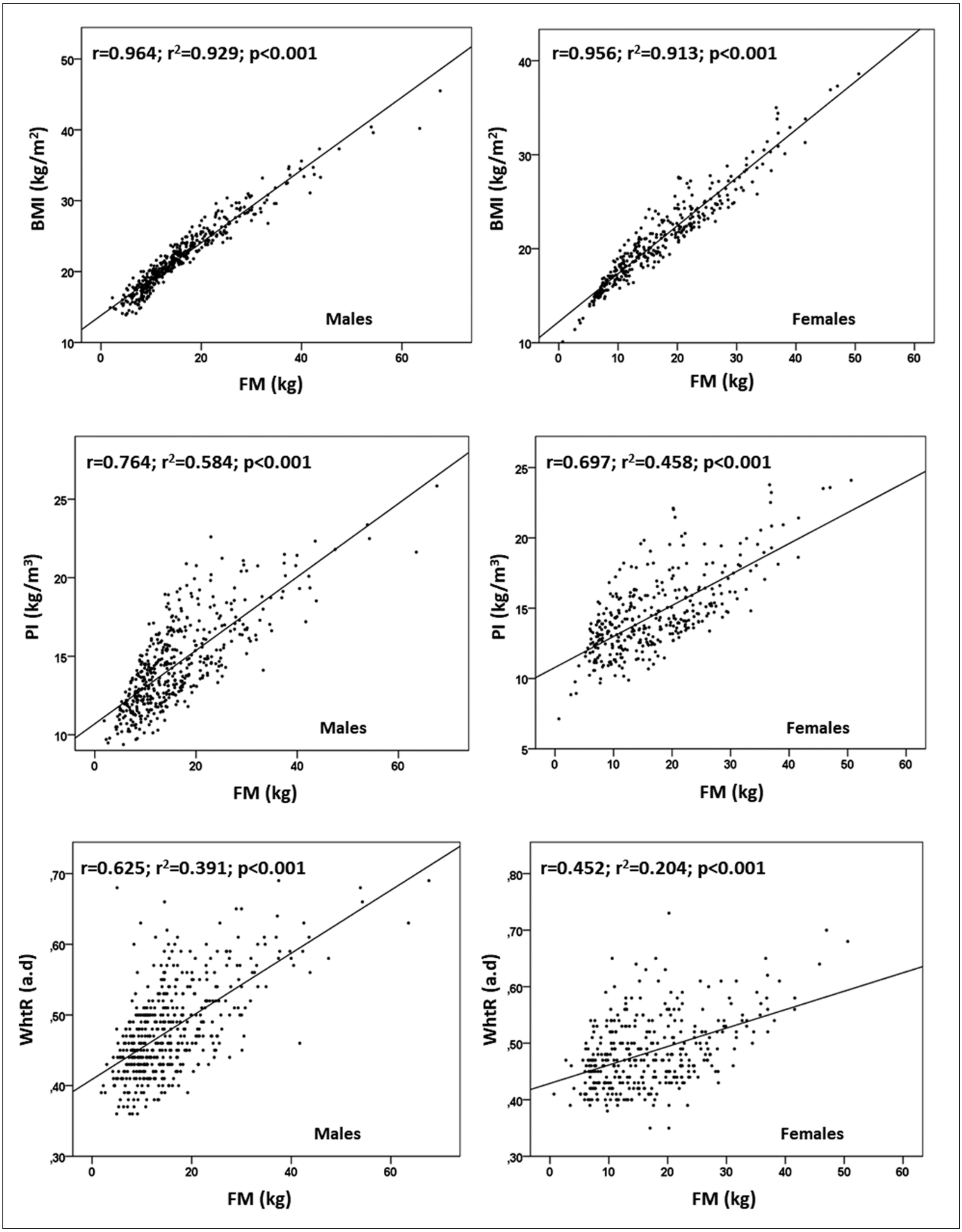

Figure 1. Relationship between fat mass (FM) and anthropometric indicators (BMI=body mass index, PI=weight index, WHI=waist-height index) in both sexes.

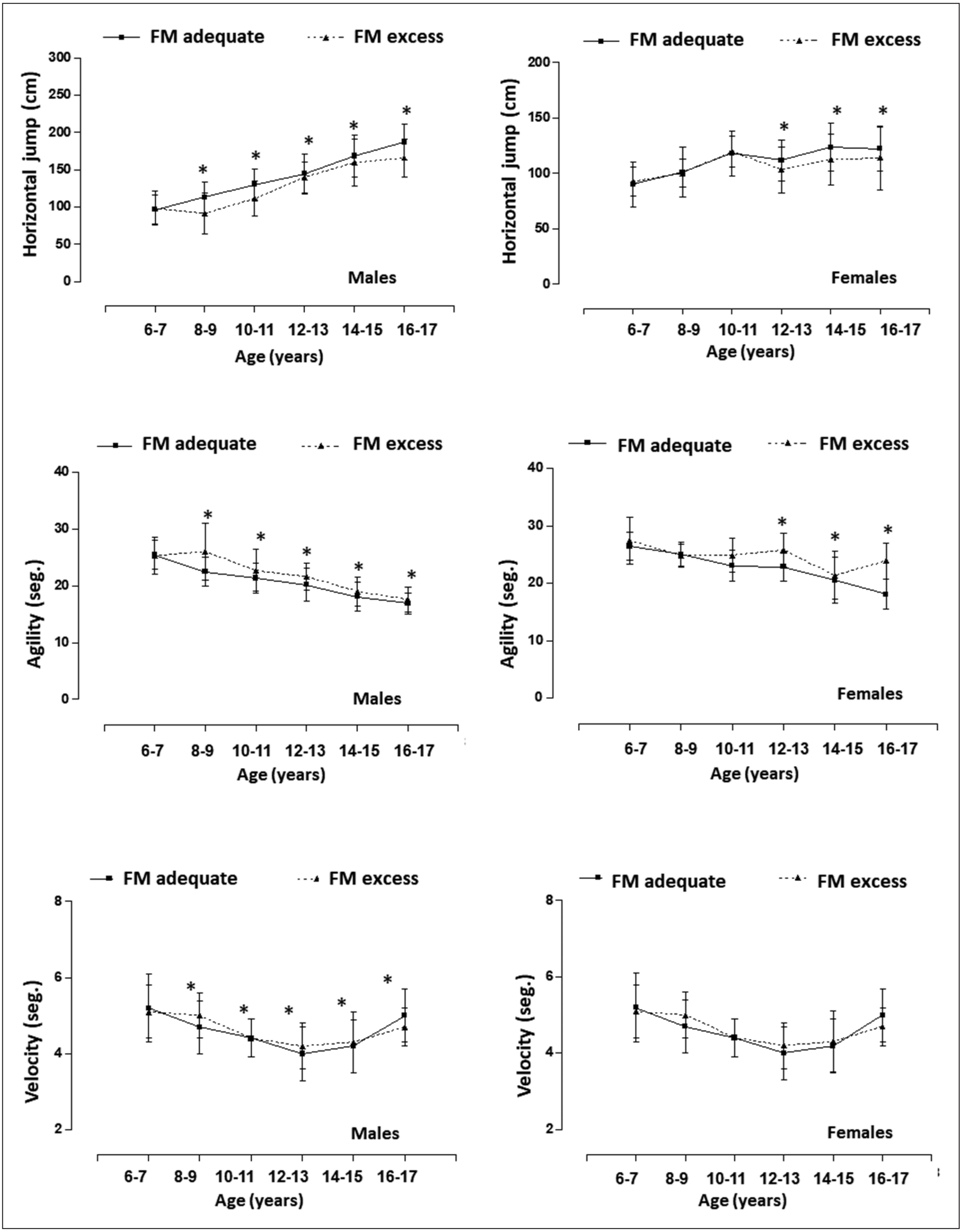

Figure 2. Comparison of physical performance of children and adolescents categorized as having adequate and excess fat mass (FFM). *Significant difference in relation to the group with adequate fat mass.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

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