LOCALIZED FAT-FREE MASS DOES NOT INFLUENCE MUSCLE STRENGTH IN OBESE AND NON-OBESE BOYS

MASSA LIVRE DE GORDURA LOCALIZADA NÃO INFLUENCIA FORÇA MUSCULAR EM RAPAZES OBESOS E NÃO OBESOS

MASA LIBRE DE GRASA LOCALIZADA NO INFLUENCIA LA FUERZA MUSCULAR EN JÓVENES OBESOSY NO OBESOS

Original Article
Artigo Original
Artículo Original

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ABSTRACT

Introduction: Obesity in adolescents has increased worldwide, and is generally associated with poor eating habits and physical inactivity. Objective: To compare absolute and relative muscle strength with body mass (BM), fat-free mass (FFM) and localized FFM of upper and lower limbs among obese and non-obese adolescents. Methods: BM, height and body mass index (BMI) were verified in 39 male adolescents (aged 13-17 years). Body composition was measured by dual-energy X-ray absorptiometry (DXA) and maximal strength of upper and lower limbs was estimated by a one-repetition maximum (1RM) test. Participants were divided into three groups: eutrophic (normal weight) (n=11), overweight (n=14), and obese (n=14). One-way ANOVA was used to compare the variables, followed by a Bonferroni post-hoc test for multiple comparisons. Pearson's correlation coefficient was used for relevant correlations and multiple linear regression to verify the influence of anthropometric variables, body composition and muscle strength of upper and lower limbs. Results: Obese and overweight adolescents had absolute muscle strength values similar to those of the eutrophic adolescents, which were lower when corrected by BM ($p<0.001$). However, muscle strength related to FFM and localized FFM were similar between groups in both upper and lower limbs. Linear regression showed that BMI explained 59% of the variation in absolute muscle strength of the lower limbs ($\beta=0.59$, $p<0.05$), FFM explained 84% of the variation in absolute muscle strength of the upper limbs ($\beta=0.84$, $p<0.01$) and 68% of the lower limbs ($\beta=0.68$; $p<0.01$), while localized FM was inversely associated in the lower limbs ($\beta=-0.53$, $p<0.05$). Conclusion: Muscle strength of lower and upper limbs, when corrected by localized FFM, does not distinguish between overweight and normal weight adolescents, indicating that obesity does not have a negative effect on generation of muscle strength in obese boys. ***Level of Evidence III; Case-control study.***

Keywords: Adolescent; Obesity; Muscle strength.

RESUMO

Introdução: A obesidade em adolescentes tem aumentado em todo o mundo, geralmente associada a hábitos alimentares inadequados e inatividade física. Objetivo: Comparar a força muscular absoluta e relativa com a massa corporal (MC), massa livre de gordura (MLG) e MLG localizada dos membros superiores e inferiores entre adolescentes obesos e não obesos. Métodos: Em 39 adolescentes do sexo masculino (entre 13 e 17 anos) foram verificados MC, estatura e índice de massa corporal (IMC). A composição corporal foi medida por absorciometria de raios-x de dupla energia (DXA) e a força máxima de membros superiores e inferiores foi estimada por um teste de repetição máxima (1RM). Os participantes foram divididos em três grupos: eutrófico (n = 11), sobrepeso (n = 14) e obeso (n = 14). Utilizou-se o teste One-way ANOVA para comparar as variáveis, seguido de teste post hoc de Bonferroni para comparações múltiplas, para as correlações relevantes, usou-se o coeficiente de correlação de Pearson e a regressão linear múltipla foi usada para verificar a influência das variáveis antropométricas, composição corporal e a força muscular dos membros superiores e inferiores. Resultados: Os adolescentes obesos e com sobrepeso tinham força muscular absoluta similar aos dos eutróficos, sendo menores quando corrigidas pela MC ($p < 0,001$). Porém, a força muscular relacionada com a MLG e a MLG localizada foi semelhante entre os grupos, tanto em membros superiores como inferiores. A regressão linear mostrou que o IMC explicou 59% da variação da força muscular absoluta dos membros inferiores ($\beta = 0,59$, $p < 0,05$), a MLG explicou 84% da variação da força muscular absoluta dos membros superiores ($\beta = 0,84$, $p < 0,01$) e 68% dos membros inferiores ($\beta = 0,68$; $p < 0,01$), enquanto a massa gorda localizada foi inversamente associada nos membros inferiores ($\beta = -0,53$; $p < 0,05$). Conclusão: A força muscular dos membros superiores e inferiores, quando corrigida pela MLG localizada, não diferencia adolescentes com sobrepeso e eutróficos, indicando que a obesidade não afeta negativamente a geração de força muscular em rapazes obesos. ***Nível de Evidência III; Estudo de caso-controle.***

Descritores: *Adolescente; Obesidade; Força muscular.*

RESUMEN

Introducción: La obesidad en adolescentes ha aumentado en todo el mundo, generalmente asociada a malos hábitos alimenticios y falta de actividad física. Objetivo: Comparar fuerza muscular absoluta y relativa de la masa corporal (MC), MLG y MLG localizada en miembros inferiores y superiores entre adolescentes obesos y no obesos. Métodos: Se verificó en 39 adolescentes hombres (entre 13 y 17 años) sus MC, estaturas e índices de masa corporal (IMC).

La composición corporal fue mensurada por absorciometría de rayos-x de doble energía (DXA) y el test de repetición máxima para estimar la fuerza máxima de miembros superiores e inferiores, divididos en tres grupos: 11 eutróficos, 14 con sobrepeso y 14 obesos. Se usó ANOVA (one way) para comparación de variables, seguido de Post Hoc de Bonferroni para comparaciones múltiples, correlaciones por el coeficiente de correlación Pearson y Regresión Lineal Múltiple para la influencia de variables antropométricas, composición corporal y fuerza muscular de miembros inferiores y superiores. Resultados: Obesos y con sobrepeso presentaron valores de fuerza muscular absoluta similares a los eutróficos, pero menor si se corrigen por MC (p<0,001). Sin embargo, la fuerza muscular relativa a MLG y MLG localizada fue semejante. En regresión lineal, el IMC explicó el 59% de variación de fuerza muscular absoluta en miembros inferiores (β=0,59, p<0,05), MLG 84% de variación de fuerza muscular absoluta en miembros superiores (β=0,84, p<0,01) y 68% en miembros inferiores (β=0,68; p<0,01), mientras que la MG localizada fue inversamente asociada a los superiores (β=-0,53; p<0,05). Conclusión: La fuerza muscular de miembros superiores e inferiores, cuando es corregida por la MLG localizada, no se diferencia en adolescentes con sobrepeso y eutróficos, indicando que la obesidad no afecta negativamente la generación de fuerza muscular en jóvenes obesos. ***Nivel de Evidencia III; Estudio caso-control.***

Descriptores: *Adolescente; Obesidad; Fuerza Muscular.*

DOI: http://dx.doi.org/10.1590/1517-869220182405156640 Article received on 11/16/2015 accepted on 08/31/2017

INTRODUCTION

Obesity is an important public health problem worldwide that affects all age ranges and is commonly associated with inappropriate eating habits and physical inactivity.[1-3] The relationships of obesity with cardiovascular and metabolic risk factors has already been well established;[4] however, the impact of excess body fat on the functional capacities of adolescents requires more thorough exploration.[5] According to previous studies, physical aptitude is inversely associated with body fat[6] and cardiovascular risk factors.[7] Muscular strength plays a vital role in preventing chronic, degenerative diseases[8] and is inversely associated with metabolic risks in adolescents.[9, 10]

Studies of muscular strength in adolescents observed higher absolute muscular strength values in obese adolescents than in non-obese adolescents,[11-13] regardless of sex. These findings can likely be attributed to neuromuscular adaptation induced by excess body weight,[13] which mainly overloads the lower limbs.[12] Nevertheless, obese adolescents were found to have a lower level of muscular strength when the absolute results were adjusted for body mass (BM). Studies that adjusted analyses for fat-free mass (FFM) yielded divergent results wherein obese and normal weight adolescents exhibited similar levels of muscular strength[12,13] or a greater level of muscular strength was observed among obese adolescents.[11] These divergences may be due to inter-study differences in variables, such as population characteristics, strength evaluation techniques and, in part, body composition assessment methods.

Thus, the specific adjustment by the localized FFM of lower limbs was another aspect that was analyzed by utilizing dual energy x-ray absorptiometry (DXA), whose results demonstrated greater muscular strength in the lower limbs of obese boys than of a non-obese control group.[11] However, no study has verified whether the specific FFM of the upper limbs similarly contributes to neuromuscular adaptation as a result of excess body weight.[11] Therefore, this study aimed to compare the muscular strengths of the upper and lower limbs in obese and non-obese male adolescents and to correlate these values with the localized FFM specific to the muscular region evaluated in each tested movement.

METHODS

This cross-sectional study included 39 male adolescent volunteers (age range: 13–17 years) from a public school in Curitiba, PR. The individuals were selected by convenience sampling. After receiving an explanation and agreeing with the study procedures, the participants and their parents or guardians signed informed consent forms that were approved by the ethics committee for Research on Human Beings of the Clinical Hospital of the Federal University of Paraná (protocol no. 2460.067/2011-03). Each subject was allocated to one of three groups—normal weight (n=11), overweight (n=14), and obese (n=14)—according to cutoff points proposed by the World Health Organization.[3] The exclusion criteria were: a) cardiorespiratory disease, osteoarthritis, or any other contraindication for undergoing the tests and b) participation in any type of regular physical activity besides physical education classes at school.

BM was measured in kilograms on a Filizola® scale (resolution = 100 g). Height was measured using a stadiometer attached to the scale (average resolution = 0.1 cm). BMI was calculated using the following formula: weight (kg)/height (m)^2. The BMI Z-score was determined using the *WHO antro* program. Subjects with BMI value scores between ≥z -2 and <z +1 on the BMI curve for age were classified as normal weight; those with scores between ≥z +1 and <z +2 as overweight; and those with scores ≥ z +2 as obese.[3] Body composition was measured via DXA, using a Lunar® *Prodigy Primo* device. The built-in software automatically determined the fat mass (FM); FFM; localized total masses in the torso (TM torso), arm (TM arm), and leg (TM leg); and localized FFMs in the torso (FFM torso), arm (FFM arm), and leg (FFM leg). An experienced pediatrician conducted a visual pubertal evaluation and classified pubic hairs between stages IV and V, based on the staging proposed by Tanner.[14]

The 1RM test was used to determine the maximum strength, based on the protocol established by Brown and Weir.[15] The groups were advised to appear at the laboratory three times, always at the same time of day to avoid a circadian influence. Only one experienced evaluator performed the tests to avoid inter-evaluator effects. The first visit to the laboratory involved familiarization with the test equipment, while the 1RM test was conducted during the second and third visits. The visits were scheduled on nonconsecutive days at intervals of at least 72 hours to prevent residual effects of the previous sessions. The proposed exercises—bench press, leg press, and bicep curl—were performed in the same order during all visits. The third visit allowed the researchers to confirm the 1RM load from the second session or to add more weight to the load if necessary. The largest load obtained during the final visit was recorded for the 1RM value. Measurements of the strengths of the upper and lower limbs were evaluated as the absolute strength and by the lifted load (LL), which considered the total load used in the equipment and the TM of the limb executing the movement during each exercise in the 1RM test. Specifically, the bench press and LL bicep curl associated with the TM arm while the LL leg press associated with the TM leg, according to the collected DXA values. Maximum strength was also analyzed relatively by dividing the LL by the BM, FFM, and localized FFM in each test.

For the data analysis, descriptive statistics with means and standard deviations were used to characterize the sample and present data. To compare the proportions of stage IV and V sexual maturity among the groups, the chi-squared test (χ^2) was applied. The Shapiro–Wilk test was used to evaluate the normality of the data, and a one-way analysis of variance was used to compare the descriptive variables, followed by the Bonferroni post-hoc test for multiple comparisons. The Pearson correlation coefficient was used to verify correlations between the lifted loads (upper and lower limbs) and the anthropometric and body composition variables while accounting for the scale of magnitude of the correlations proposed by Dancey and Reidy (2005): weak (r = 0.10–0.30); moderate (r = 0.40–0.60); and strong (r = 0.70–1). A multiple linear regression analysis model was constructed to determine the influences of anthropometric and body composition variables (independent variables) and the muscular strengths (LL) of the upper and lower limbs (dependent variable). A significance level of $p<0.05$ was adopted for the analysis.

RESULTS

Table 1 presents the general characteristics of the sample. The study groups did not differ in age, height, or pubertal stage.[14] However, the FM and BMI were significantly greater in the obese ($p<0.001$) and overweight ($p<0.001$) groups than in the normal weight group as a consequence of the division of the groups. Obese and overweight adolescents did not differ with respect to BM, although both had greater values when compared to the normal weight group. There were no differences among the three groups with respect to FFM (kg). Nonetheless, the percentage value was greater in the normal weight group than in the other groups, and in the overweight group than in the obese group ($p<0.001$). The FFM Arm and FFM Leg values were greater for obese and overweight individuals than for normal weight individuals ($p<0.001$). Normal weight adolescents had significantly lower bone mineral density (BMD) values when compared to the overweight group ($p<0.05$); no significant differences in this parameter were observed in other groupwise comparisons.

Table 1. Anthropometric characteristics of the sample expressed as means and standard deviations.

Variables	Obese	Overweight	Normal Weight	F	p
	(n=14)	(n=14)	(n=11)		
Age (years)	14.2±0.89	14.4±1.28	14.1±0.98	0.207	0.81
Tanner (IV/V)	7/7	7/7	6/5	#0.65	0.96
BM (kg)	87.8±17.2	79.8±13.1^{b**}	58.7±5.86^{c***}	15.07	<0.0001
Height (m)	1.69±0.07	1.73±0.06	1.72±0.06	1.15	0.32
BMI (kg/m^2)	30.2±4.35^{a**}	26.2±2.71^{b***}	19.8±1.60^{c***}	32.70	<0.0001
BMD	2.83±0.44	2.89±0.50^{b*}	2.45±0.33	3.48	0.04
FM (%)	38.4±4.42^{a**}	30.4±6.12^{b***}	15.2±4.70^{c***}	63.26	<0.0001
FM (kg)	33.9±10.2^{a**}	24.7±8.40^{b***}	9.01±3.48^{c***}	28.72	<0.0001
FFM (%)	58.2±4.15^{a**}	65.8±5.98^{b***}	80.6±4.79^{c***}	61.15	<0.0001
FFM (kg)	50.4±7.95	51.4±5.77	47.0±3.72	1.66	0.20
TM Torso (kg)	40.7±10.1	36.0±6.40^{b**}	25.7±2.47^{c***}	13.25	<0.0001
TM Leg (kg)	32.4±6.37	29.6±5.71^{b**}	21.5±2.15^{c***}	13.95	<0.0001
TM Arm (kg)	9.10±1.44	8.53±1.60^{b**}	6.54±0.80^{c***}	11.57	<0.0001
FFM Torso (kg)	23.0±4.20	23.2±2.62	21.1±1.74	1.63	0.20
FFM Leg (kg)	18.1±2.87	18.6±2.24	16.4±1.47	2.82	0.07
FFM Arm (kg)	5.70±0.98	6.05±1.05	5.59±0.65	0.86	0.49

BM=body mass; BMI=body mass index; FM=fat mass; FFM=fat free mass; TM=total mass; ^{a}Obese vs. Overweight; ^{b}Overweight vs. Normal Weight; ^{c}Obese vs. Normal Weight; $^*p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$; # comparisons among proportions using the chi-squared test.

Table 2 presents the absolute and LL muscular strengths of the upper and lower limbs. As shown in the table, no significant differences were detected among the groups.

Table 3 presents the LL values adjusted for the Total FFM and localized FFM; as shown, no statistical differences were observed among the groups. Regardless, a comparison of the LL values relative to BM revealed that the obese ($p<0.001$) and overweight ($p<0.001$) adolescents had less muscular strength in the upper and lower limbs, compared to normal weight adolescents.

Table 4 presents the Pearson coefficients of correlations between LL in the strength tests and body composition and anthropometric variables. The LL results correlated directly with BMI and FFM (LL bench press: r=0.42, P=0.00 and r=0.74, P=0.00, respectively; LL leg press: r=0.51, P=0.00 and r=0.75, P=0.00, respectively; and LL bicep curl: r=0.38, P=0.01 and r=0.72, P=0.00, respectively). The %FM correlated weakly with all the muscular strength tests.

According to a linear regression analysis, the BMI explained 59% of the variation in the absolute muscular strength of the lower limbs ($\beta=0.59$, $p<0.05$), while the FFM accounted for 84% and 68% of the variations in the absolute strengths of the upper and lower limbs, respectively. Furthermore, the appendicular FM was inversely associated with the lower limb strength ($\beta=-0.53$; $p<0.05$).

Table 2. Measurements of absolute and lifted load muscular strengths.

Variables	Obese	Overweight	Normal Weight	P
	(n=14)	(n=14)	(n=11)	
Absolute Bench Press (kg)	41.5±9.00	45.1±9.78	41.6±11.0	0.54
Absolute Leg Press (kg)	204.4±55.5	199.2±51.0	192.7±40.2	0.84
Absolute Bicep Curl (kg)	22.2±4.62	24.8±9.78	23.6±5.18	0.43
LL Bench Press	50.5±10.1	53.7±10.9	48.1±11.5	0.44
LL Leg Press	236±59.3	228.9±54.6	214.2±40.3	0.57
LL Bicep Curl	31.31±5.62	33.3±7.29	30.1±5.73	0.43

LL=Lifted Load; ^{a}Obese vs. Overweight; ^{b}Overweight vs. Normal Weight; ^{c}Obese vs. Normal Weight; $^{**}p<0.01$; $^{***}p<0.001$.

Table 3. Measurements of relative muscular strength.

Variables	Obese	Overweight	Normal Weight	P
	(n=14)	(n=14)	(n=11)	
LL Bench Press / BM	0.58±0.07	0.68±0.12^{b**}	0.82±0.17^{c***}	<0.001
LL Leg Press / BM	2.73±56	2.88±43^{b**}	3.67±64 ^{c***}	<0.001
LL Bicep Curl / BM	0.36±0.05	0.42±0.07^{b**}	0.51±0.09^{c***}	<0.001
LL Bench Press / FFM (kg)	0.99±0.08	1.02±0.12	1.02±0.21	0.89
LL Leg Press /FFM (kg)	4.68±0.85	4.39±0.62	4.55±0.72	0.58
LL Bicep Curl / FFM (kg)	0.62±0.11	0.63±0.08	0.64±0.06	0.83
LL Bench Press /FFM torso	2.19±0.25	2.30±0.32	2.27±0.48	0.71
LL Leg Press /FFM leg	13.0±2.46	12.1±1.75	13.0±2.23	0.48
LL Bicep Curl /FFM arm	5.49±0.42	5.48±0.38	5.33±0.62	0.68

LL=Lifted Load; BM=body mass; FFM=fat free mass; ^{a}Obese vs. Overweight; ^{b}Overweight vs. Normal Weight; ^{c}Obese vs. Normal Weight; $^{**}p<0.05$; $^{***}p<0.001$.

Table 4. Matrix of Pearson coefficient values for correlations of the lifted loads for leg press, bench press, and bicep curls with anthropometric and body composition variables in obese, overweight, and normal weight individuals.

	LL Bench Press	LL Bicep Curl	BMI	%FM	FFM
LL Leg Press	.878**	.865**	.511**	.196	.759**
LL Bench Press		.929**	.425**	.109	.745**
LL Bicep Curl			.380*	.085	.722**
BMI				.890**	.583**
%FM					.302

LL = lifted load; BMI = body mass index; %FM = fat mass percentage; FFM = fat free mass; *$p<0.05$; **$p<0.01$; NS=not significant.

DISCUSSION

This study compared the muscular strengths of the upper and lower limbs between obese and non-obese male adolescents and adjusted the absolute results for the BM, Total FFM, and localized FFM, which correspond to the muscular structures used in the movements proposed by the 1RM test. The levels of muscular strength in the upper and lower limbs of the obese and overweight boys were similar to those of the normal weight boys. These findings contradict previous studies that identified increased muscular strength in extremely obese adolescent boys,[11] obese girls,[12] and obese children of both sexes[13] relative to non-obese control groups. These previous findings were justified by the neuromuscular adaptations that occur in obese individuals as a consequence of a body mass overload on the lower limbs.[12,13] However, differences among the studies may be attributable to differences in the population characteristics, as well as disparities in age and evaluation methods. Notwithstanding, the results revealed that the muscular strength of upper limbs did not differ from that of the lower limbs after adjusting for the localized FFM, indicating that the neuromuscular adaptations observed in the lower limbs are also present in the upper limbs.

Other studies have reported greater bone and muscle masses and greater levels of absolute muscular strength among obese adolescents[11,12] and children,[13] compared to their non-obese counterparts. These findings have been attributed to the presence of an altered metabolic profile associated with obesity; this profile is characterized by increased levels in insulin,[16] which can induce a systemic anabolic state in obese individuals when associated with the additional overload of the excess weight on the musculoskeletal structure.[13] According to the results in this study, obese and non-obese boys had similar absolute strengths. However, a recent study that compared the lower and upper limb strengths of obese and non-obese female adolescents observed greater levels of absolute strength in the lower limbs of obese subjects. However, no difference was observed between the groups when strength was expressed relative to the FFM determined via bioelectrical impedance.[12] Conversely, it is important to highlight potential sex-related differences in the distribution of excess body fat during adolescence. In boys, accumulated fat is distributed from the extremities to the torso, whereas in girls, a contrasting pattern appears; these differences are attributed to modifications in estrogen and testosterone levels during puberty.[17] These data suggest that in boys, the muscular strength undergoes a smaller overload of excess fat due to the more centralized distribution, which leads to relatively less resistance and neuromuscular adaptation in boys than in girls. Although BMI was among the variables that best explained the muscular strength of the lower limbs (59%), consistent with previous observations in girls,[12] the lower limbs were not more mechanically affected than the upper limbs with regard to the musculoskeletal structures. Furthermore, the obese boys did not demonstrate a favorable adaptation of muscular strength in comparison to normal weight boys.

DXA facilitates an analysis of the body composition by body segment,[19] which allows for the adjustment of muscular strength by the localized FFM. In this study, the results for the upper and lower limbs reached equivalence, which could be explained by the similar FFM values in both groups, despite differences in BMI among the sample. In a study of the maximum torque in the knees of obese and normal weight boys,[11] the absolute muscular strength was greater in the obese group. However, the results were equivalent after adjusting for total FFM. However, when the muscular strength was expressed only using the FFM of the thigh, the obese group exhibited greater torque, compared to the normal weight control group. Nevertheless, these adolescents exhibited severe obesity and a greater FFM relative to the normal weight adolescents; given the characteristics of the sample in this study, these differences might have influenced the results. Notwithstanding, this was the first study to use the FFM of the upper limbs to adjust for muscular strength. The results suggest that the overload sustained by the additional weight contributed by fat in the arms leads to neuromuscular adaptation. However, the upper limb joints do not support the same level of overload as the lower limbs, as the muscular strength relative to the localized FFM responded similarly in a comparison of obese, overweight, and normal weight individuals.

This study had some limitations, including the small number of subjects, and thus caution is needed when generalizing the results. Additionally, strength was not measured using isokinetic equipment, which is considered the gold standard for such analyses. However, we used the 1RM test, a potentially important tool that is more applicable to professionals involved with the prescription of physical exercise.[18] Furthermore, this study evaluates a relatively underinvestigated area by considering the weight on the test equipment and the mass of the limbs in use when measuring the maximum strength produced during the test. Notably, this was the first study of adolescents to compare muscular strength relative to the localized FFMs of the upper and lower limbs during movements required by the strength tests. Because this was a cross-sectional study, a causal relationship between obesity and muscular strength could not be established. Therefore, assessing the strengths of different segments might improve the application of prescribed physical exercises for obese adolescents by identifying the characteristics of this group and ensuring safety during the execution of the most appropriate physical exercises for this population.[20]

In conclusion, the main findings of this study demonstrate the lack of difference in the muscular strengths of the upper and lower limbs of boys with excess weight and with normal weight after adjusting for the total and localized FFM. These results indicate that obesity did not negatively affect the generation of muscular strength in our sample. Accordingly, neuromuscular adaptations were not observed in the upper and lower limbs, as the muscular strength was not influenced by the total additional body mass in our sample. Future studies are needed to verify whether similar effects of the FM and localized FFM on muscular strength would occur in a sample of female adolescents.

ACKNOWLEDGMENTS

We would like to thank the Araucária Foundation for financing this project, the Center for Innovative Therapies for conducting body composition tests (DXA), and the College of the State Military Police of Paraná for offering their space and for providing the subjects for the study. The first, third, and fourth authors are master's and doctorate fellows of CAPES. The last author is a productivity fellow of CNPq.

All authors declare no potential conflict of interest related to this article.

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. FBMJ (0000-0002-9001-6123)* was the lead author of the manuscript. NL (0000-0002-4752-6697)* and RBR (0000-0003-4035-106X)* revised and approved the content of the manuscript. PRC (0000-0003-0727-6029)* performed the medical assessment for the exclusion criteria and pubertal assessment. CTA (0000-0001-6499-775X)* and LRS (0000-0003-3111-5364)* participated in the collection of anthropometric data and monitored the adolescents in the dual-energy X-ray absorptiometry (DXA) test. FBMJ, ICJ (0000-0002-1072-9028)* and WAL (0000-0001-7895-6799)* participated actively in the application of the one-repetition maximum (1RM) test for strength assessment. All the authors contributed to the discussion of results and to the intellectual content of the study. *ORCID (Open Researcher and Contributor ID).

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