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Effects of 16 weeks of Muay Thai training on the body composition of overweight/obese adolescents

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Key words: obesity, overweight, adolescents, training, martial arts

Abstract

Background. To analyze the effects of 16 weeks of Muay Thai training on the body composition of overweight/obese adolescents.

Problem and Aim. The objective of study is to analyze the effects of 16 weeks of Muay Thai training on the body composition (fat mass, lean mass, and bone mass) of overweight/obese adolescents.

Methods. Thirty-three overweight / obese adolescents, aged between 10 and 17 participated in the study, being allocated to the training (n=18) and control (n=15) groups. Anthropometric measurements and body composition were measured using dual energy X-ray absorptiometry, in which the variables of body mass, body fat, fat mass, lean mass, density, and bone mineral content, were collected by total and by segment.

Results. After 16 weeks of training with MT, the effect on a significant group, with changes in body mass was observed (ΔMT = 0.79; ΔControl = -0.21), body fat percentage (ΔMT = -2.89; ΔControl = -0.67), total fat mass (ΔMT = -1.78; ΔControl = -0.6), fat mass of the arms (ΔMT = -0.38; ΔControl = -0.01), trunk fat (ΔMT = -2.74; ΔControl = -0.16) and android fat (ΔMT = -2.8; ΔControl = -0.62). The mean total lean mass (MM) (ΔMT = 2.81; ΔControl = 0.27) and the MM of the legs (ΔMT = 1.2; ΔControl = 0.1).

Conclusions. Training with MT caused significant increases MM in total and in the legs.

Introduction

Overweight and obesity are major cardiovascular risk factors in the pediatric population, affecting approximately 20-25% of children and adolescents [Rivera *et al.* 2014, Brady *et al.* 2017]. Overweight children present a major problem, given that they are more likely to become overweight adults [Travers *et al.* 2002]. Exercise training and improvements in eating habits, lifestyle changes, have been recommended as a cornerstone in the treatment of obese adolescents [Brown *et al.* 2018].

Martial arts are popular exercise modes in youth. However, the majority of studies involving martial arts are with athletes, aiming at sports performance, or with the incidence of injuries [Crisafulli *et al.* 2009; Vaseenon *et al.* 2015; Strotmeyer *et al.* 2017]. Studies that have aimed to analyze the effect of martial arts on the health of children and adolescents are still incipient in the literature. Tsang *et al.* [2009] observed benefits to body composition, such as increased lean mass and bone mineral density, of obese adolescents after a kung-fu training program. However, some factors that may exert influence on body composition such as adolescent development and growth, changes in eating habits, and an increase in daily physical activity, are not usually controlled in the analyzes. Thus, adjustment for maturational control, food intake, and the practice of physical activity are fundamental aspects to be controlled by studies that aim to analyze the efficacy of different interventions in the body composition of obese populations. Muay Thai could be an alternative method of exercise to improve the health of its practitioners.

Specifically, Muay Thai is a dynamic modality [Crisafulli *et al.* 2009], involving the whole body, including wrists, elbows, knees, and shins or feet. During a Muay Thai match, maximum oxygen uptake can reach up to 90% [Crisafulli *et al.* 2009; Rapkiewicz *et al.* 2018].We compared two types of weekly frequency of Muay Thai training on body composition and physical fitness in healthy woman and observed improvement in all physical fitness variables investigated, without any significant changes in body composition, for both groups. However, in addition to being older and healthier individuals, there was absence of the control group to compare the effectiveness of training, used equipment to measure body composition with low accuracy, and adjustment variables such as food intake and physical activity level were not used. Therefore, the present study has been advancing in this direction.

Thus, our hypothesis was that Muay Thai training would provide gains in lean mass, reduction in fat mass, and increases in bone mass after a period of intervention compared to the control group. Thus, the objective of the present study was to analyze the effects of 16 weeks of Muay Thai training on the body composition (fat mass, lean mass, and bone mass) of overweight/obese adolescents.

Methods

Participants

The sample of the present study was formed by adolescents between the ages of 10 and 17. All adolescents were part of an extension and research project, realized in the first semester of 2016, linked to the Universidade Estadual Paulista – UNESP, in the city of Presidente Prudente – Sao Paulo located in the southeast of Brazil.

The calculation of the sample size for two independent samples considered a standard deviation of 11.5 for the control group and 10.6 for the Muay Thai group [Christofaro *et al.* 2013], a 5% alpha error, and a power of 80% in which the required number of subjects was 20 subjects. Considering possible losses, 20% was added, totalizing 24 subjects, 12 in each group (control and Muay Thai). The control group was advised to remain without any type of systematized training for 16 weeks and had the benefit of receiving evaluations on health parameters.

Sample recruitment was performed by means of dissemination in media resources, so the interested parties contacted the person in charge of the project, and then presented themselves at the CELAPAM Laboratory at FCT/UNESP together with their parents or legal guardians. The initial screening was then performed, conferring the following inclusion criteria: (a) classified as obese or overweight by the Body Mass Index (BMI), following criteria published by Cole *et al.* [2000] and by the percentage of body fat following Williams *et al.* [1992]; (b) being aged between 10 and 17 at the time of the evaluation, considered as adolescents according to the World Health Organization [WHO 2000]; (c) not presenting any clinical problem that would prevent the practice of physical activities; (d) the parents or legal guardians signed the formal consent form for participation in the program; (e) presenting a medical certificate stating the possibility of the adolescent to practice physical exercises. This project was approved by the Research Ethics Committee of FCT/UNESP (CAAE: 26702414.0.0000.5402, Opinion Ethics Committee Number: 549.549).

After enrollment according to the criteria, 74 young people were recruited, of which 40 were assigned to the Muay Thai group and 34 to the control group. After 16 weeks, 41 youths were excluded from the sample (19 from the control group and 22 from the Muay Thai group) for not completing the assessments, dropping out, or exceeding the allowed number of absences (25%). Thus, 33 adolescents were included in the analysis, of which 15 adolescents were distributed in the control group, aged 12.07±2.21 (11 boys and 4 girls), of which 9 were obese and 6 overweight, and 18 in the training group, aged 12.61±2.09 (10 boys and 8 girls), of which 13 were obese and five overweight. The young people underwent anthropometric measurements, body composition assessments, and answered questionnaires. All evaluations were repeated at the end of the study in both groups: exercise and control.

Primary Outcome Measures

Body Composition

The dual-energy x-ray absorptiometry (DXA) technique was used to analyze the body composition and distribution of body fat, using the equipment GE Lunar – DPX-NT. The radiation dose the adolescent received was less than 0.05 mrem [Laskey *et al.* 1992], that is, 50 times less than an X-ray examination. The exam lasts approximately 15 minutes. When placed in the device, the adolescents remained in a supine position throughout the examination. The scanner quality was tested by a trained researcher prior to each day of measurement, following the manufacturer’s recommendations.

The method estimates body composition by fractionating the body into three anatomical compartments: fat free mass, fat mass, and bone mineral content. This technique also allows these three compartments to be evaluated in total and per body segment. Thus, body mass (BM DXA) variables were measured in kilograms (kg), body fat (BF) in kg and percentage (%), lean mass (LM) total, of arms and legs in kg, fat mass (FM) of arms and legs in kg, BF of trunk in %, BF android and BF gynoid also in %, in addition to bone mineral density (BMD) in grams (g) and bone mineral content (BMC) in grams per square centimeters (g/cm^2) of arms, legs, trunk, pelvis, column and total. The precision of the machine in terms of coefficient of variation was 0.66% (n=30 subjects not involved in this study) and all scans were carried out in a temperature-controlled laboratory at the university.

Secondary Outcome Measures

Anthropometric measurements

Body mass was measured using a Filizola brand electronic scale, with a precision of 0.1 kg and a maximum capacity of 150 kg, height using a stadiometer of the Sanny brand with an accuracy of 0.1 cm and maximum extension of two meters, and trunk height with the same stadiometer, but seated on a 50 cm high bench. All measurements were performed according to the methodology proposed [Gordon *et al.* 1998]. From these measures, the BMI was calculated using the equation: body mass in kg, divided by height in meters, squared, as well as somatic maturation using the equation proposed by Mirwald *et al.* [2002].

Somatic Maturation

Somatic maturation was calculated using the Maturity Offset estimation formula for adolescents, developed by Mirwald *et al.* [2002], in which the anthropometric measures of weight, height, trunk-cephalic height, and leg length are used. When the result presents negative values they represent the years that are still lacking for the individual to reach the peak and positive values the years that the individual has already passed the peak. For each gender a different formula is used:

Male

$- 9.236 + 0.0002708 * (\mathbf{LL} * \mathbf{TH}) – 0.001663 * (\mathbf{A} * \mathbf{LL}) + 0.007216 * (\mathbf{A} * \mathbf{TH}) + 0.02292 * (\mathbf{W}/\mathbf{H})$

Female

$- 9.376 + 0.0001882 * (\mathbf{LL} * \mathbf{TH}) + 0.0022 * (\mathbf{A} * \mathbf{LL}) + 0.005841 * (\mathbf{A} * \mathbf{TH}) – 0.002658 * (\mathbf{A} * \mathbf{W}) + 0.07693 * (\mathbf{W}/\mathbf{H})$

Where **LL** is the leg length (cm), **TH** is trunk-cephalic height (cm), **A** is age (years), **W** is weight (kg), and **H** is height (cm). This variable was used as an adjustment in the analyzes. In addition, the age of peak height velocity (APHV) was also calculated by subtracting the Maturity Offset from age.

Food Frequency

To quantify the habitual food consumption and frequency in the adolescents, a food frequency questionnaire for adolescents (QFFA) was used, developed and validated by Slater *et al.* [2003], which includes 94 food items. Each item includes seven frequencies: never, less than once a month, one to three times a month, once a week, two to four times a week, once a day, and two or more times a day. These items were distributed into five groups: i) Fruits and vegetables; (ii) Sweets and additional sugar; (iii) Natural juices with added sugar; (iv) Artificial beverages with added sugar; and v) Foods with a high lipid content. The ticked frequency of each food belonging to each group was summed and divided by the amount of food that was destined for that group. These groups were used as adjustment variables in the analyzes.

Physical Activity Level

In order to measure the level of physical activity practice, the questionnaire proposed by Baecke *et al.* [1982] was used, consisting of 16 questions, with scores varying from one to five for the answers, divided into three dimensions: school, sports, and leisure. From the responses, the physical activity indices for each of the dimensions were calculated according to the author's proposal [Baecke *et al.* 1982] and the sum of these indices gave the total index of physical activity practice. This variable was used to control the practice of physical activity outside the intervention period during the 16 weeks and as an adjustment in the analyzes.

Intervention

Muay Thai Training

The intervention consisted of 16-weeks of Muay Thai training, with four weeks being allocated for familiarization and adaptation, as the individuals were insufficiently physically active. The classes took place three times a week on non-consecutive days, each training session lasting one and a half hours, and the class was always divided into general exercises, specific exercises, combat simulation, and/or play activities. The general exercises were composed of 30 minutes of warm-up and physical stretching, taking into account the specificity of the modality. The specific exercises lasted 40 minutes and were punching, elbowing, kicking, defenses, and knees and elbows, against partners wearing protection of kickers, mitts, Thai pads, gloves, and shin guards. In the simulation of fight and/or play activities actions of initiation in the practice of the Muay Thai percussion modality were given, involving opposition games, games of speed, achievement of objects, of imbalance, and also with specific movements using apparatus according to recommendations of the literature in the area [Franchini *et al.* 2012].

These activities remained in the moderate to high intensity, evaluated through the subjective perception of effort scale proposed by Borg *et al.* [1987], adapted by Foster [Foster *et al.* 1998], and shown to participants shortly after each session. The intensity was measured by this scale instead of a heart rate monitor since the use of a heart rate monitor is not recommended in contact sports, as it could cause abrasions. After 16 weeks all initial evaluations were performed again.

Comparator Group

The control group did not perform any fight training and were advised not to change their eating habits or physical activity practice during the study. Control participants received the benefit of the monitoring of all variables analyzed during the 16 weeks. The control group performed all assessments before and after 16 weeks, in the same way as the Muay Thai group.

Statistical Methods

The Kolmogorov Smirnov test was used to verify the normality of the data and the Student t test for independent samples was used to compare the intervention group with the control group at baseline. The variance homogeneity was verified by means of Levene's test and the analysis of variances (ANOVA) of repeated measures was performed with adjustment for gender, age, BMI, somatic maturation, physical activity level, and food frequency. The delta value (Δ) was calculated by subtraction of moment two (M2) from moment one (M1) to verify the differences. Pearson's correlation was performed to relate the deltas of the clinical variables to the adjustment variables. All analyzes were performed using the Statistical Package for Social Sciences – SPSS for Windows (version 13.0, SPSS Inc, Chicago, IL), with a significance level of p-value <5%.

Table 1. Description of the sample and comparison of groups at the baseline moment, Presidente Prudente, São Paulo. Brazil, 2016.

	Muay Thai (n=18) Mean (SD)	Control (n=15) Mean (SD)	*p*-value
Age (years)	12.61 (2.09)	12.07 (2.21)	.477
Body mass (kg)	73.13 (19.03)	69.22 (17.97)	.549
Height (cm)	159.71 (10.45)	158.27 (11.76)	.716
BMI (kg/m²)	28.13 (4.10)	27.24 (4.58)	.567
APHV (years)	14.45 (1.08)	14.81 (0.88)	.313
Maturity Offset (years)	-2.38 (1.37)	-2.20 (1.30)	.698
Physical Activity Level (score)	10.36 (2.46)	11.71 (1.71)	.173
Fruits and vegetables (score)	1.56 (1.07)	2.20 (1.06)	.114
Sweets and additional sugar (score)	1.77 (1.77)	2.33 (2.33)	.094
Natural juices with AS (score)	1.25 (0.86)	1.71 (1.52)	.288
Artificial beverages with AS (score)	1.40 (0.95)	1.76 (1.24)	.362
Foods with a HLC (score)	1.46 (0.56)	1.81 (0.99)	.227
BM DXA (kg)	71.21 (19.02)	68.52 (17.73)	.678
BF (%)	44.67 (6.41)	39.90 (5.65)	**0.031**
FM (kg)	32.38 (11.47)	27.70 (9.71)	.214
LM Total (kg)	36.28 (8.71)	38.59 (9.14)	.466
LM of Arms (kg)	4.01 (1.15)	4.30 (1.13)	.484
LM of Legs (kg)	13.22 (3.34)	14.20 (3.58)	.426
FM of Arms (kg)	2.40 (1.00)	1.92 (0.98)	.175
FM of Legs (kg)	12.82 (4.44)	10.87 (3.79)	.191
BF of Trunk (%)	48.80 (7.34)	44.02 (5.29)	**0.038**
BF Android (%)	52.23 (6.63)	47.97 (6.21)	.066
BF Gynoid (%)	52.29 (5.56)	48.10 (5.02)	**0.030**
BMD of Arms (g/cm²)	0.777 (0.116)	0.730 (0.097)	.221
BMC of Arms (g)	264.48 (87.16)	251.37 (69.71)	.634
BMD of Legs (g/cm²)	1.226 (0.143)	1.160 (0.136)	.188
BMC of Legs(g)	981. 15 (277.91)	904.94 (234.58)	.400
BMD of Trunk (g/cm²)	0.965 (0.144)	0.908 (0.097)	.202
BMC of Trunk (g)	828.80 (269.45)	679.05 (189.95)	.072
BMD of Pelvis (g/cm²)	1.176 (0.185)	1.106 (0.125)	.212
BMC of Pelvis (g)	295.95 (96.33)	251.27 (77.29)	.150
BMD of Column (g/cm²)	1.107 (0.202)	1.002 (0.157)	.105
BMC of Column (g)	218.84 (69.37)	179.02 (52.90)	.071
BMD Total (g/cm²)	1.141 (0.130)	1.059 (0.103)	.054
BMC Total (g)	2541.23 (702.68)	2217.06 (509.74)	.136

SD= standard deviation; kg/m²= kilograms per meter squared; BMI= body mass index; APHV= age of peak height velocity; AS= added sugar; HLC= high lipid content; kg= kilograms; %= percentage; g/cm²= grams per centimeter squared; g= grams; BM= body mass; DXA= dual-energy x-ray absorptiometry; BF= body fat; FM= fat mass; LM= lean mass; BMD= bone mineral density; BMC= bone mineral content; bold= p-value<0.05.

Results

At the initial moment, the characteristics of the adolescents who gave up (n=22) were compared with the adolescents who completed the training (n=18). There was a difference between weight (dropout 86.73±20.02, training 73.13±19.03, p-value=0.034), BMI (dropout 32.27±5.51, training 28.13±4.10; p-value=0.010), total body mass (dropout 84.80±19.77, training 71.21±19.02, p-value=0.034), total lean mass (dropout 44.61±11.51, training 36.28±8.71, p-value=0.013), lean mass of arms (dropout 4.99±1.34, training 4.01±1.15, p-value=0.018), and lean mass of legs (dropout 15.82±3.88, training 13.22±3.34, p-value=0.029). In addition, the average training frequency was calculated, being 84.29±10.72%.

Table 1 presents the characterization variables of the sample comparing the two groups (control and Muay Thai) at the baseline moment, and significant differences were observed between the groups for BF, BF of trunk, and BF gynoid, with higher values for the Muay Thai group.

In order to verify the possible relationships of the clinical variables with the adjustment variables, these relationships with the deltas were analyzed. There was

Table 2. Effect of Muay Thai intervention on body fat in overweight/obese adolescents, Presidente Prudente, São Paulo. Brazil, 2016.

	Muay Thai (n=18) Mean[a] (SE)		Δ	Control (n=15) Mean[a] (SE)		Δ	Effect	*p*-value
	M1	M2		M1	M2			
BM DXA (kg)	72.99 (0.74)	73.98 (1.16)	0.79	69.54 (1.13)	69.33 (1.78)	-0.21	**Group** Time Interaction	**0.029** .440 .554
BF (%)	44.60 (0.83)	41.71 (0.89)	-2.89	39.17 (1.28)	38.50 (1.36)	-0.67	**Group** Time Interaction	**0.019** .518 .073
FM Total (kg)	33.10 (0.77)	31.32 (1.04)	-1.78	27.52 (1.18)	26.92 (1.60)	-0.6	**Group** Time Interaction	**0.009** .923 .474
FM of Arms (kg)	2.46 (0.11)	2.08 (0.10)	-0.38	1.88 (0.17)	1.87 (0.15)	-0.01	**Group** Time Interaction	**0.047** .793 .794
FM of Legs (kg)	12.56 (0.43)	12.01 (0.54)	-0.55	11.51 (0.64)	10.96 (0.79)	-0.55	Group Time Interaction	.268 .492 .993
BF of Trunk (%)	49.16 (0.94)	46.42 (1.17)	-2.74	42.87 (1.44)	42.71 (1.79)	-0.16	**Group** Time Interaction	**0.024** .596 .125
BF Android (%)	52.73 (0.89)	49.93 (1.24)	-2.8	46.34 (1.36)	45.72 (1.90)	-0.62	**Group** Time Interaction	**0.022** .364 .126
BF Gynoid (%)	51.66 (0.91)	48.55 (0.74)	-3.11	47.92 (1.39)	46.83 (1.14)	-1.09	Group Time Interaction	.101 .479 .105

M1= baseline moment; M2= moment after 16 weeks; SE= standard error; ES= effect size; kg= kilograms; %= percentage; BM= body mass; DXA= dual-energy x-ray absorptiometry; BF= body fat; FM= fat mass; p-value>0.05 adjusted by , age, BMI, *Maturity Offset*, physical activity level. and food frequency.

Table 3. Effect of Muay Thai intervention on lean mass in overweight/obese adolescents, Presidente Prudente, São Paulo. Brazil, 2016.

	Muay Thai (n=18) Mean[a] (SE)		Δ	Control (n=15) Mean[a] (SE)		Δ	Effect	*p*-value
	M1	M2		M1	M2			
LM Total (kg)	37.28 (0.66)	40.09 (0.73)	2.81	39.77 (1.01)	40.04 (1.11)	0.27	Group Time **Interaction**	.360 .210 **0.033**
LM of Arms (kg)	4.16 (0.10)	4.32 (0.19)	0.16	4.38 (0.16)	4.58 (0.30)	0.2	Group Time Interaction	.411 .551 .879
LM of Legs (kg)	13.56 (0.25)	14.76 (0.23)	1.2	14.76 (0.39)	14.86 (0.36)	0.1	Group Time **Interaction**	.157 .782 **0.030**

M1= baseline moment; M2= moment after 16 weeks; SE= standard error; ES= effect size; kg= kilograms; LM= lean mass; p-value>0.05 adjusted by , age, BMI, *Maturity Offset*, physical activity level. and food frequency.

a relation of ΔFM with age (r= -0.437; p-value= 0.011) and Maturity Offset (r= -0.401; p-value= 0.021), of the ΔBF of trunk also with age (r= -0.400; p-valor= 0.021) and Maturity Offset (r= -0.345; p-value=0.049), and the ΔFM of arms with age (r= -0.357; p-value= 0.041) and BMI (r= -0.352; p-value= 0.044).

Tables 2 and 3 present the comparison of M1 and M2 for fat and total lean mass composition by segment between the control and training groups, adjusted for age, , BMI, somatic maturation, physical activity level, and food frequency. Thus, differences between groups were observed only for BM DXA, BF, FM total and arms, BF trunk, and BF android, however considering the delta values, the training group presented greater reductions when compared to the control group. In addition, a difference was observed when analyzing the effect of group and time interaction for LM total and legs, in which the Muay Thai group presented significant increases.

Table 4 compare M1 with M2, with the same adjustments, between the groups (control and Muay Thai), but analyzing the total and per segment bone composition content and density. There were no significant differences between values, however according to the deltas, it can be considered that the control group presented more favorable behavior of the variables, with an increase and the opposite for the Muay Thai group.

Figure 1 presents graphs with individual delta values for total body fat, total mass, total bone mineral density, and total bone mineral content.

Table 4. Effect of the Muay Thai intervention on the bone mineral density and content of overweight/obese adolescents. Presidente Prudente-SP. Brazil. 2016.

	Muay Thai (n=18) Mean[a] (SE)		Δ	Control (n=15) Mean[a] (SE)		Δ	Effect	*p*-value
	M1	M2		M1	M2			
BMD of Arms (g/cm²)	0.78 (0.01)	0.79 (0.02)	0.01	0.74 (0.02)	0.76 (0.03)	0.02	Group Time Interaction	.263 .649 .732
BMD of Legs (g/cm²)	1.24 (0.02)	1.25 (0.02)	0.01	1.16 (0.03)	1.19 (0.03)	0.03	Group Time Interaction	.152 .404 .324
BMD of Trunk (g/cm²)	0.97 (0.02)	0.98 (0.02)	0.01	0.91 (0.03)	0.95 (0.04)	0.04	Group Time Interaction	.415 .681 .302
BMD de Pelvis (g/cm²)	1.19 (0.03)	1.21 (0.03)	0.02	1.11 (0.05)	1.16 (0.05)	0.05	Group Time Interaction	.341 .644 .647
BMD of Column (g/cm²)	1.12 (0.03)	1.08 (0.04)	-0.04	1.01 (0.05)	1.10 (0.06)	0.09	Group Time Interaction	.504 .668 .054
BMD Total (g/cm²)	1.14 (0.02)	1.15 (0.02)	0.01	1.07 (0.03)	1.09 (0.03)	0.02	Group Time Interaction	.120 .870 .503
BMC of Arms (g)	271.02 (10.33)	267.74 (15.25)	-3.28	259.03 (15.80)	268.85 (23.32)	9.82	Group Time Interaction	.818 .793 .594
BMC of Legs (g)	1005.51 (33.50)	1012.13 (30.49)	6.62	911.91 (51.22)	950.92 (46.62)	39.01	Group Time Interaction	.238 .946 .208
BMC of Trunk(g)	861.26 (33.51)	832.66 (49.28)	-28.6	682.45 (51.24)	746.24 (75.35)	63.79	Group Time Interaction	.094 .994 .270
BMC of Pelvis (g)	309.86 (12.11)	306.51 (19.45)	-3.35	253.13 (18.52)	283.32 (29.74)	30.19	Group Time Interaction	.185 .966 .283
BMC of Column (g)	224.51 (10.03)	216.90 (11.94)	-7.61	187.42 (15.33)	189.74 (18.25)	2.32	Group Time Interaction	.140 .904 .539
BMC Total (g)	2601.13 (87.91)	2567.76 (101.67)	-33.37	2245.13 (134.41)	2356.01 (155.44)	110.88	Group Time Interaction	.132 .978 .296

M1= baseline moment; M2= moment after 16 weeks; SE= standard error; ES= effect size; g/cm²= grams per centimeters squared; BMD= bone mineral density; g= grams; BMC= bone mineral content; p-value>0.05 adjusted by , age, BMI, *Maturity Offset*, physical activity level, and food frequency.

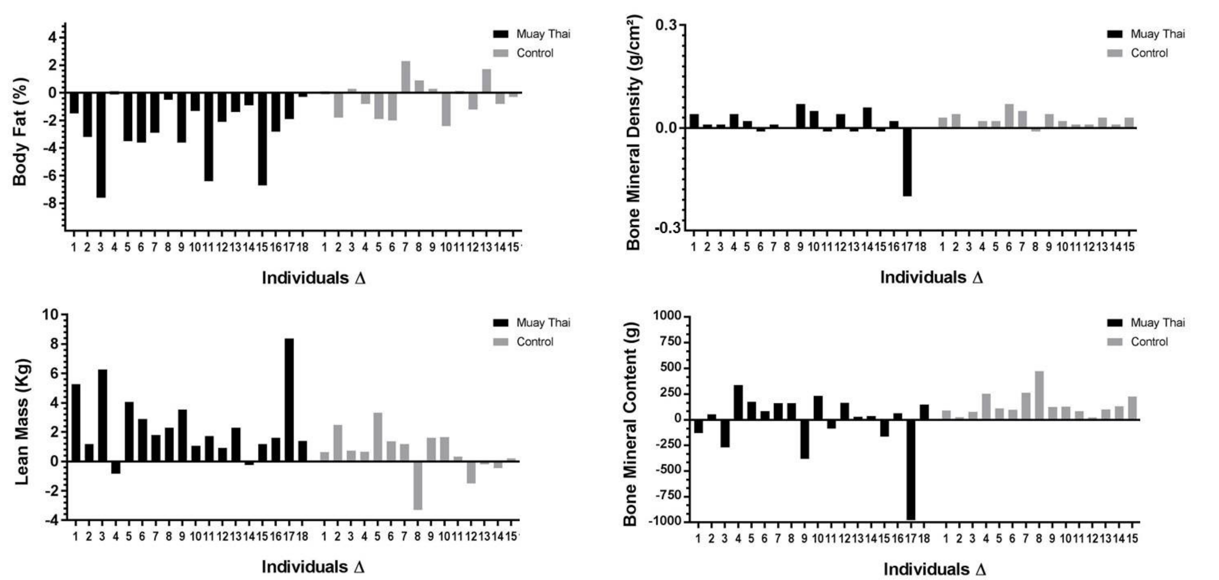

Figure 1. Graphic of individual delta values of each group (Muay Thai n=18; Control n=15) for the variables total body fat, total lean mass, and total bone mineral content and mineral density of overweight/obese adolescents

Discussion

The present study aimed to analyze the effects of 16 weeks of Muay Thai training on body composition (fat, lean mass, density, and bone mineral content) of overweight/obese adolescents. According to the results, in relation to body fat, there was a significant difference between groups. The adolescents who underwent Muay Thai training presented greater reductions in body fat, although this difference was not significant for the control group. For lean mass there was a difference between group and time interaction, in which adolescents undergoing Muay Thai training demonstrated greater increases in lean mass. Regarding bone composition, there were no significant differences between the groups.

Although there were no significant differences after the 16-week Muay Thai intervention on BF, clinically significant reductions (-2.86%) were observed in the delta. In some studies, the reductions are higher, obtaining significant differences, such as the study by Benson *et al.* [2008] who after eight weeks of progressive high-intensity resistance training observed a reduction of 1.8% in BF in children. Watts *et al.* [2004] who performed an eight-week intervention in obese adolescents with circuit training also found significantly reduced BF (-0.6%). Other impact sports such as soccer after 12 weeks of practice in obese adolescents also presented reductions in BF (-2.2%) [Vasconcellos *et al.* 2016], with values closer to the finding in the present study.

However, studies comparing intermittent training with continuous training observed reductions in body fat in both models, with similar results [Mosher *et al.* 2005; Tjonna *et al.* 2008]. Thus, since the Muay Thai modality has an intermittent character, the lack of significant reduction in BF may be because the intervals between the exercises were large, or the intensity in general was not sufficient to produce high energy expenditure or increase fat oxidation, as presented in the study of Tsang *et al.* [2009]. In addition, studies report that when dealing with pediatric populations there are greater challenges to control weight, due to the difficulties of recruitment and retention as well as the need to work on health related aspects with the family [Warren *et al.* 2007].

Differently from the present study, Ito *et al.* [2016], in a cross-sectional analysis with eutrophic adolescents, compared the control group with the martial arts group (Judo, Karate, and Kung-fu) and observed lower lean mass values for the control group, although they did not present statistical difference, in addition to which there was no difference in body fat and both total and segmental BMD were higher in the martial arts group. Partially corroborating with the findings of the present study Tsang *et al.* [2009] observed that after a 6-month Kung-fu intervention there was an increase in the lean mass of obese adolescents who performed Kung-fu training. However, this difference was observed only in the time effect, with both the Kung-fu intervention group and the control group presenting increases in the same variables, emphasizing the importance of adjustment for confounding factors. This can be explained due to sports with explosion, power, and high impact characteristics such as Kung fu, Karate, and Muay Thai providing increases in lean body mass [Imamura *et al.* 1996; Tsang *et al.* 2009; Crisafulli *et al.* 2009].

In the present study, no significant differences were observed in BMD and BMC among overweight adolescents of the Muay Thai group when compared to the control group. These findings are contrary to Tsang *et al.*

[Tsang *et al*. 2009], who observed significant increases in total and spine BMD of obese adolescents undergoing Kung-fu training for of six months. Among the possible explanations for the fact that the present study did not present differences in BMD, one is that the Muay Thai group demonstrated higher values of body fat and this may have influenced the result, since there is a negative relation between abdominal fat and BMD [Junior *et al*. 2013], as excess body fat may be based on the action of adipokines produced by adipose tissue on growth mediators related to bone development [Ito *et al*. 2016]. Besides, excess adipose tissue is associated with insulin resistance and this substance plays an important role in the proliferation of osteoblasts [Junior *et al*. 2013]. Another hypothesis is that the intervention time proposed in the present study was not sufficient for BMD increments. Meyer *et al*. [2011] suggest that the intervention time for greater BMD gains in this infant-juvenile period is at least six months, although Meyer *et al*. [2011] presented positive results in BMD of children and adolescents after 9 months of exercise.

As limitations of the present study we consider the lack of randomization of the sample. Another factor is the sample size, which can be considered small, and the groups were different at baseline for some variables. However, the main strengths of this study are the risk population who performed the intervention (young overweight people) and the fact that we attempted to perform statistical analysis recommended in randomized clinical trials, presenting possible differences between the groups and not only within the groups, as advocated by the CONSORT [Moher *et al*. 2001], and adjusting for confounding factors such as age, gender, Maturity Offset, BMI, food frequency, and physical activity practice, factors that may exert influence on body composition and that were controlled in this study.

Conclusions

It can be concluded, therefore, that three times a week for 90 minutes, during 16 weeks, the Muay Thai training provided significant increases in total and leg lean mass, as well as a tendency to reduce body fat and did not influence the bone composition of overweight/obese adolescents. Despite not being randomized and the small sample size, in this study, Muay Thai appears to be an exercise modality that can contribute to the improvement in body composition of obese adolescents, thus becoming an alternative and dynamic modality of physical exercise.

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Abbreviations

MT, Muay Thai; LM, lean mass; BMI, body mass index; BF, body fat; FM, fat mass; BMD, bone mineral density; BMC, bone mineral content; DXA, dual-energy x-ray absorptiometry; LL, leg length; TH, trunk-cephalic height; A, age; W, weight; H, height; APHV, age of peak height velocity; ANOVA, analysis of variances; M2, moment two; M1, moment one.

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Wpływ 16-tygodniowego treningu Muay Thai na skład ciała młodzieży z nadwagą /otyłością

Słowa kluczowe: otyłość, nadwaga, młodzież, trening, sztuki walki

Streszczenie

Tło. Analiza wpływu 16-tygodniowego treningu Muay Thai na skład ciała młodzieży z nadwagą/otyłością.

Problem i cel. Celem badania była analiza wpływu 16-tygodniowego treningu Muay Thai na skład ciała (masa tkanki tłuszczowej, masa beztłuszczowa i masa kostna) młodzieży z nadwagą/otyłością.

Metody. W badaniu wzięło udział trzydziestu trzech nastolatków z nadwagą/otyłością, w wieku od 10 do 17 lat, przydzielonych do grupy treningowej (n=18) i kontrolnej (n=15). Pomiary antropometryczne i skład ciała mierzono za pomocą absorpcjometrii promieniowania rentgenowskiego o podwójnej energii, w której zmiennymi były: masa ciała, tkanka tłuszczowa, masa tkanki tłuszczowej, masa beztłuszczowa, gęstość i zawartość mineralna kości, łącznie i w poszczególnych segmentach.

Wyniki. Po 16 tygodniach treningu MT zaobserwowano statystycznie istotne efekty w grupie związane ze zmianami masy ciała (ΔMT = 0,79; ΔControl = -0,21), procentowej zawartości tkanki tłuszczowej (ΔMT = -2,89; ΔControl = -0,67), całkowitej masy tkanki tłuszczowej (ΔMT = -1,78; ΔControl = -0,6), masy tkanki tłuszczowej ramion (ΔMT = -0,38; ΔControl = -0,01), tkanki tłuszczowej tułowia (ΔMT = -2,74; ΔControl = -0,16) i tkanki tłuszczowej tarczycy (ΔMT = -2,8; ΔControl = -0,62). Średnia całkowita masa beztłuszczowa (MM) wyniosła (ΔMT = 2,81; ΔControl = 0,27) oraz MM kończyn dolnych (ΔMT = 1,2; ΔControl = 0,1).

Wnioski. Trening Muay Thai spowodował istotny wzrost średniej całkowitej beztłuszczowej masy (MM) całego ciała, w tym kończyn dolnych.