Twelve Weeks of Plyometric Training Improves Motor Performance of 7- to 9-Year-Old Boys Who Were Overweight/Obese: A Randomized Controlled Intervention

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Abstract

Nobre, GG, de Almeida, MB, Nobre, IG, dos Santos, FK, Brinco, RA, Arruda-Lima, TR, de-Vasconcelos, KL, de-Lima, JG, Borba-Neto, ME, Damasceno-Rodrigues, EM, Santos-Silva, SM, Leandro, CG, and Moura-dos-Santos, MA. Twelve weeks of plyometric training improves motor performance of 7- to 9-year-old boys who were overweight/obese: a randomized controlled intervention. *J Strength Cond Res* 31(8): 2091–2099, 2017–The prevalence of childhood overweight/obesity has increased, and physical training at school may to be effective to combat this scenario. We analyzed the effects of a protocol of plyometric training on body composition and motor performance of boys who were overweight/obese aged 7–9 years. The sample was randomly assigned into 2 groups: plyometric training group (T, $n = 40$) and control group (C, $n = 19$). Training consisted of 20 $\text{min}\cdot\text{d}^{-1}$ (twice a week, during 12 weeks) of lower extremity plyometric exercise. Health-related physical fitness was measured by handgrip strength, standing long jump (SLJ), curl-ups, sit and reach, square test, running speed, and mile run test. Gross motor coordination was evaluated by means of the *Körperkoordinations-test für Kinder* (KTK) tests. Baseline and post-intervention differences were investigated, and effect size was estimated through Cohen's *d* coefficient. Both groups showed increased body weight, height, and sitting height after intervention with a negligible effect size. Only T group showed increased fat-free mass ($p = 0.011$) compared with baseline values with small effect size. Plyometric training improved handgrip strength ($d = 0.23$), sit and reach ($d = 0.18$), curl-ups ($d = 0.39$), SLJ ($d = 0.80$), agility ($d = 0.48$), and time in the mile run test ($d = 0.38$). For gross motor coordination results, T group showed better performance in all tests after plyometric training with moderate/large effect size. Thus, 12 weeks of PT improved health-related physical fitness components and motor coordination acquisition of 7- to 9-year-old boys who were overweight/obese.

Key Words obesity, prepubescent boys, physical fitness, KTK test

Introduction

Childhood overweight/obesity is now a health public awareness around the world, mostly because approximately 70% of obese children and adolescents showed a high chance to become obese adults (17). Overweight and obesity in childhood are known to have significant impact on both physical and psychosocial (low self-esteem) health (3). Several comorbidities are associated with obesity such as type II diabetes mellitus , sleep apnea, slipped femoral epiphyses, dyslipidemia, hypertension, chronic inflammation, and cardiovascular diseases (3). The underlying factors related to excessive gain of body weight and body fat mass during childhood include genetic (Alstrom syndrome and Prader Willi syndrome), environmental factors (high caloric diet and physical inactivity), hormonal disturbs (hypothyroidism), and most recently, the prenatal and perinatal environment (maternal obesity and short duration or no breastfeeding) (29).

Obesity and overweight can be defined as an excess of body fat and high values of body mass index (BMI), respectively (13). The measurement of BMI percentile (overweight = BMI 85th to 95th percentile and obese BMI ≥

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31(8)/2091–2099

Journal of Strength and Conditioning Research
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95th percentile) for age and gender suggested by the World Health Organization (WHO) growth standards in preschool children and WHO growth reference curves (4) are the most practical tools for clinicians to identify and track overweight and obesity (13,14). Once overweight/obesity is established during infancy, a primary prevention incorporating strategies of behavioral changes, diet management, and physical activity may to be effective to revert this scenario.

Regular physical activity is associated with positive effects on health and development of children (28). A systematic review identified that most of intervention studies used programs of moderate to vigorous physical activity with duration of 30–45 minutes, 3–5 $d \cdot wk^{-1}$, for school-age youth (28). However, children and adolescents should participate daily in 60 minutes or more of moderate to vigorous physical activity to improve musculoskeletal development, cardiovascular fitness, reduction in total body, and visceral adiposity (2). Although most of the outcome variables showed significant improvements after the intervention (diet and physical activity), the low adherence for an active lifestyle still remains a serious problem to maintain especially overweight children on a physical training program (23). The underlying mechanism is multifactorial, and seems to include low level of health-related physical fitness and motor coordination that causes demotivation for children who were overweight/obese to engage in sports and leisure activities (10).

Plyometric exercise refers to the performance of stretch-shortening cycle movements that involve a high-intensity eccentric contraction immediately after a rapid and powerful concentric contraction (21). This type of exercise can improve balance, jumping abilities, speed reaction, muscular strength, vertical jump height, and power production (26). In response to 8-week training period (plyometric plus balance exercises), it was observed improved leg stiffness, 10-m sprints and shuttle runs to a high degree in children (5). A program of plyometric training (total number of jumps 60 per session, which was gradually increased over a period of 10 weeks to 100 jumps per session) for prepubescent boys (11.1 ± 0.5 years old) improved the performance in squat jump and running speed by influencing the maximum velocity phase, but not the acceleration phase (19).

Currently, less is known about the influence of plyometric exercise on children who were overweight/obese. Children who were overweight/obese have lower levels of health-related physical fitness, motor coordination, and therefore participate in few organized recreational activities (16). Plyometric training is considered to be safe and recommended to improve health-related physical fitness and motor coordination of youth according to the National Strength and Conditioning Association (12). Additionally, there are no previous studies that considered this kind of physical training in children who were overweight/obese. Thus, the purpose of the present study was to examine the effects of 12 weeks of plyometric training on body composition, the performance in health-related physical fitness tests and gross motor coordination in 7- to 9-year-old boys who were overweight/obese. Our hypothesis is that plyometric training increases fat-free mass (FFM) and improves the performance in motor skill tests of schoolboys who were overweight/obese.

Methods

Experimental Approach to the Problem

To precisely investigate the effects of 12-week of plyometric training on body composition, health-physical fitness and gross motor coordination, schoolboys who were overweight/obese were assigned into 2 groups: plyometric training group (T, $n = 40$) and control group (C, $n = 19$). This is a 2-armed interventional study with pretest and posttest measures. To investigate differences between baseline and postintervention, effect size was estimated through Cohen's d coefficient. The trained group exercised 20 $min \cdot d^{-1}$, twice a week (on nonconsecutive days) during 12 weeks, with a progressive increment of intensity during the weeks. These exercise included low-intensity exercises (lateral jump), moderate exercises (squat jump), and high-intensity jumps (increasing height). Groups were evaluated before and after plyometric training. All variables were analyzed before and after intervention for both groups. Anthropometry and body composition were evaluated using a standard protocol. Health-related physical fitness was evaluated by handgrip strength, standing long jump (SLJ), curl-ups, flexibility (sit and reach), agility (square test), running speed, and mile run test (estimated $\dot{V}O_2max$). For motor gross coordination, we used the protocol based on KTK tests that included: (a) balance; (b) jumping laterally; (c) hopping on one leg over an obstacle; and (d) shifting platforms. Motor quotient was calculated based on the score of each test.

Subjects

Fifty-nine 7- to 9-year-old schoolboys who were overweight/obese were invited to participate in the study. Written informed consent from parents or legal guardians was a criterion for the inclusion of each child in the study. To identify boys who were overweight/obese, the measurement of BMI percentile (overweight = BMI 85th to 95th percentile and obese BMI ≥ 95th percentile) for age and gender suggested by the WHO growth standards in preschool children and WHO growth reference curves was used (4). This study was approved by the Ethics Committee of the Center of Health Science, Federal University of Pernambuco (CEPSH/CCS/UFPE, CAAE 04723412400005208) in accordance with the ethical standards of the 1964 Declaration of Helsinki.

The sample was then randomly assigned into 2 groups: plyometric training group (T, $n = 40$) and control group (C, $n = 19$). In this study, to minimize reduction of the sample, the proportion of 2:1 for plyometric training group versus control group was used. All study procedures took place at school facilities. Before data collection, all children participated in one introductory session and research assistants demonstrated proper testing procedures and participants practiced each test. Children were asked not to perform

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TABLE 1. Description of the different jumps used in the protocol of plyometric physical training.

Type of jump	Description
Lateral jump	Jump with both feet, side-to-side movements alternating floor and the 10 cm platform
Squat jump	Jump with a rapid eccentric contraction forcefully off the floor at the top of the range of motion feet together after the fall of 10 cm platform
Increasing height jump	Jump alternating between the ground and the platforms with increasing heights (10, 20, 30, and 40 cm)
Decreasing height jump	Jumps alternating between the ground and the platforms with decreasing heights (40, 30, 20, and 10 cm)
One-legged vertical jump left	Repetitions of maximum jumps to touch the ground with only the left foot
One-legged vertical jump right	Repetitions of maximum jumps to touch the ground with only the right foot
Different height jump	Steps between 30, 20, 40, 10, 30-cm platforms without touch in the ground
Increasing height jump + squat jump	Increased jumps 10, 20, 30 and 40 cm, followed by a leap grouped after the fall of 40 cm from the platform

any vigorous physical activity the day before or the day of any study procedure. Pretesting was performed the week before the training period and posttesting was performed the week after the training period.

Anthropometry and Body Composition

The body weight of the lightly dressed and barefooted subjects was measured to the nearest 0.1 kg with a digital scale (Filizola, São Paulo, Brazil), and the stretched stature was measured to the nearest 0.5 cm using a portable stadiometer (Sanny, São Paulo, Brazil) with each subject's shoes off, feet together, and head in the Frankfurt horizontal plane (22). The BMI was calculated using the standard formula (weight [kilogram]/height^2 [meter]). Triceps and subscapular skinfolds were measured with a Lange caliper (Lange, Santa Cruz, CA, USA) using

TABLE 2. Description of plyometric training.

Week	Sets	Jumps/set	Total number of jumps	Type of jumps
1–2	10	5	50	Lateral jump; squat jump; different heights; increasing height and decreasing height
3–4	12	5	60	Lateral jump; squat jump; different heights; increasing height; decreasing height, and increasing height + squat jump
5	14	5	70	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right)
6	16	5	80	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right), and increasing height + squat jump
7–8	18	5	90	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right), and increasing height + squat jump
9	20	5	100	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right), and increasing height + squat jump
10–11	22	5	110	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right), and increasing height + squat jump
12	24	5	120	Lateral jump; squat jump; different heights; increasing height; decreasing height; one-legged jump (left); one-legged jump (right), and increasing height + squat jump

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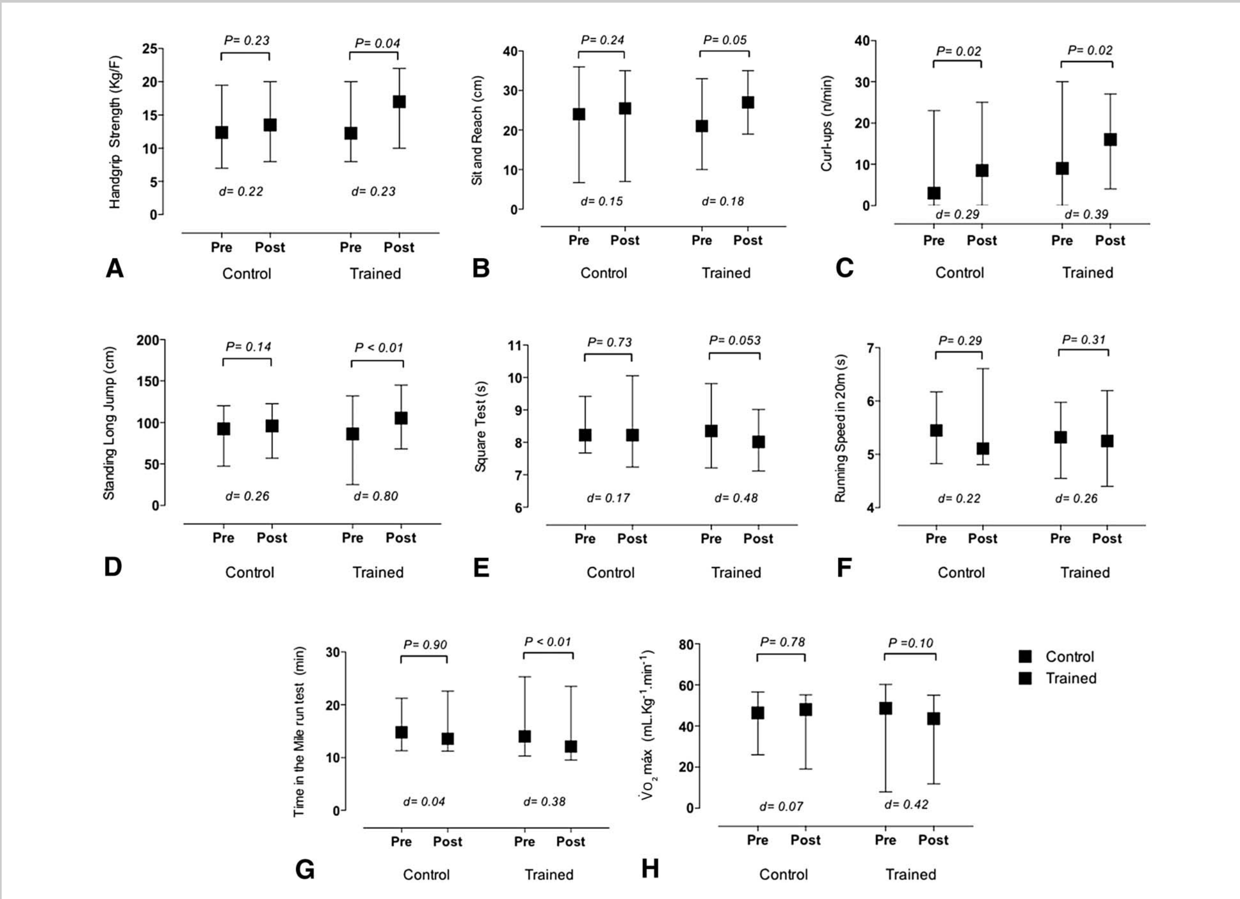

Figure 1. Variation of the performance in each physical fitness test: handgrip strength (A), sit and reach (B), curl-up (abdominal strength, C), standing long jump (D), square test (agility, E), running speed in 20 m (F), time in the mile test (G), estimated $\dot{V}O_2max$ (H) of 7- to 9-year-old children who were overweight/obese (control = 19 and trained = 40) submitted to a program of plyometric physical training during 12 weeks. Values are expressed in median, minimal and maximal. The intergroup (control × trained) differences were evaluated using Mann-Whitney *U*-test and the intragroup (pre and post) differences using Wilcoxon test. Effect size (Cohen's *d*) before and after intervention was calculated for both groups, control and trained.

a standard protocol (20). The body fat percentage, fat mass (kilogram), and FFM (kilogram) were estimated using Slaughter's formula (27).

Health-Related Physical Fitness

Health-related physical fitness was assessed according to FITNESSGRAM (24) and EUROFIT (11) standardized test batteries. For the present report, the chosen tests were (a) handgrip strength (measured independently in each hand) using a handgrip dynamometer (Saehan, Flintville, TN, USA); (b) sit and reach (as a measure of flexibility); (c) curl-ups (as an indicator of dynamic muscle endurance of abdominal muscles); (d) SLJ (a measure of the explosive power of the lower limbs); (e) square test as a measure of agility (complete a weaving running course [4×4 m^2] in the shortest possible time); (f) a 20-m dash run (to evaluate running speed in the shortest possible time); (g) time (minute) in the mile run test as a putative indicator of relative maximal oxygen consumption, where time to run the distance was transformed to; and (h) $\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$) using the regression equations from a previous study (7).

Gross Motor Coordination

Gross motor coordination was evaluated with a standardized test battery for children, which was developed in Germany (*Körper Koordination Test für Kinder*–KTK) (18), and has been widely used in Brazil. The KTK includes the assessment of the following items: (a) balance–child walks backward on a balance beam 3 m in length, but of decreasing widths: 6, 4.5, and 3 cm; (b) hopping on 1 leg over an obstacle–the child is instructed to hop on 1 foot at a time over a stack of foam squares. After a successful hop with each foot, the height is increased by adding a square ($50 \times 20 \times 5$ cm); (c) jumping laterally–child makes consecutive jumps from side to side over a small beam ($60 \times 4 \times 2$ cm) as fast as possible for 15 seconds; and (d) shifting platforms, jumping from side to side–child begins by standing with both feet on 1 platform ($25 \times 25 \times 2$ cm supported on 4 legs 3.7 cm

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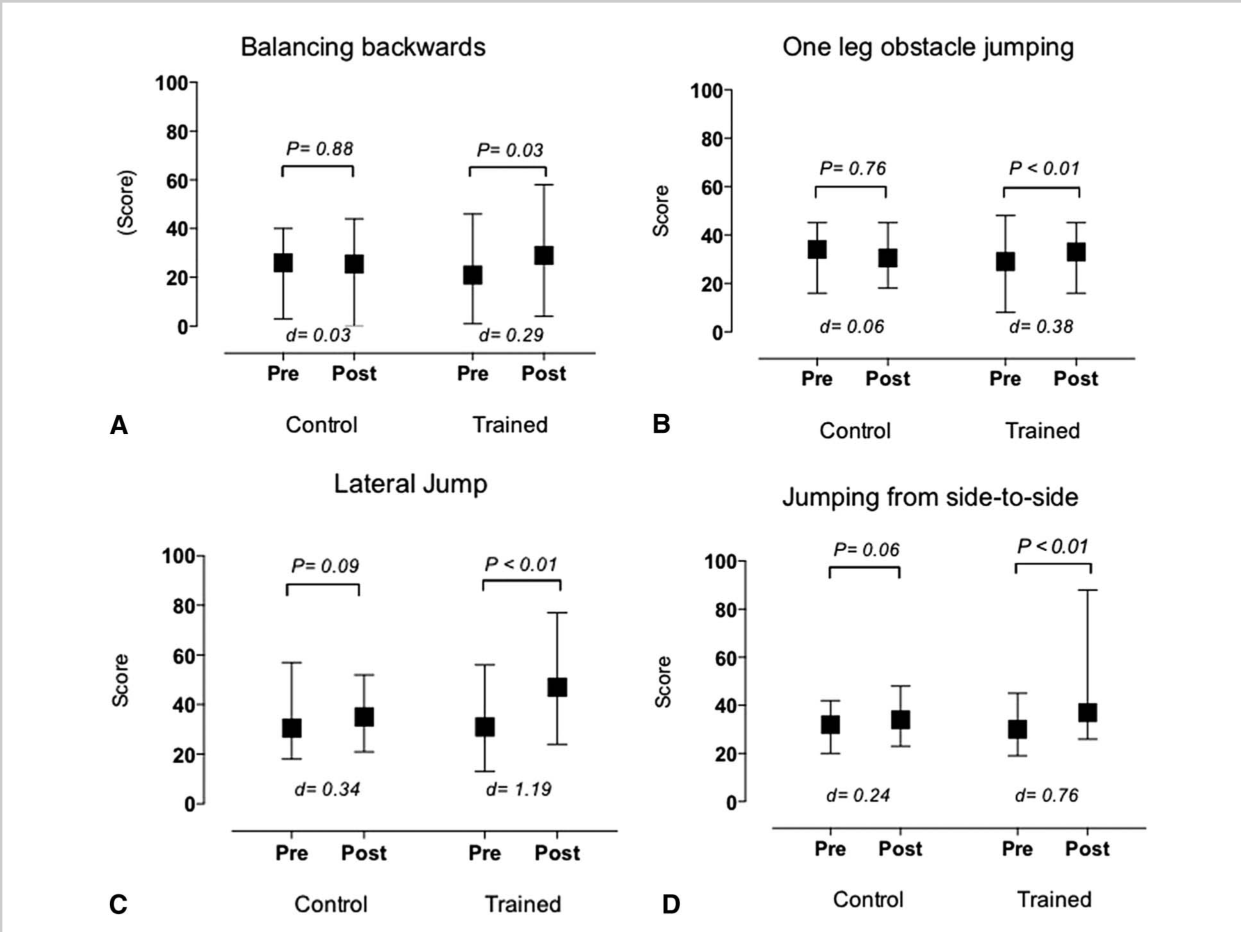

Figure 2. Variation of the performance in each gross motor coordination test: balancing backwards (A), one-legged obstacle jumping (B), lateral jump (C), and jumping from side-to-side (D) of 7- to 9-year-old children who were overweight/obese (control = 11 and trained = 7) submitted to a program of plyometric physical training during 12 weeks. Values are expressed in median, minimal and maximal. The intergroup (control × trained) differences were evaluated using Mann-Whitney *U*-test and the intragroup (pre and post) differences using Wilcoxon test. Effect size (Cohen's *d*) before and after intervention was calculated for both groups, control and trained.

high); places the second platform alongside the first and steps on to it; the first platform is then placed alongside the second and the child steps on to it; the sequence continues for 20 seconds. For each task, performance was scored in a point system as suggested by the protocol, were summed, and converted in the overall motor quotient (MQ) gender and age specific. The overall MQ qualifies gross motor development in the following categories: "not possible" (MQ < 56), "severe motor disorder" (MQ, 56–70), "moderate motor disorder" (MQ, 71–85), "normal" (MQ, 86–115), "good" (MQ, 116–130) and "high" (MQ, 131–145).

Plyometric Training

The progressive plyometric training program consisted of a set of exercise on nonconsecutive days twice per week (Tuesday and Thursday) for 12 weeks under monitored and controlled conditions. The training session for trained group was divided in 3 sections: warm-up (jogging at a self-selected comfortable pace followed by stretching during 3 minutes), training, and cool down. Throughout the study period, subjects exercised in small groups and an instructor-to-subject ratio of at least 1:3 was maintained. Level 1 included low-intensity exercises (lateral jump) to safely introduce subjects to plyometric training. In addition, level 1 exercises provided the subjects with an opportunity to gain confidence in their abilities to perform basic plyometric movements before progressing to more advanced drills at levels 2 (squat jump) and level 3 (increasing height). Each exercise session included lower-body plyometric and plyometric speed and agility drills that were specifically designed to enhance a subject's ability to accelerate, decelerate, change direction, and then accelerate again. Subjects were provided with adequate time for recovery between exercises and sets. The description of each kind of jump is presented in Table 1. If a subject fatigued and could not perform an exercise correctly, the exercise was stopped. Subjects were encouraged

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Table 3. Descriptive statistical analyses of anthropometry and body composition of the sample.*†

Anthropometry and body composition	Baseline					Post-training					Cohen's *d*: control (baseline vs. post)	Cohen's *d*: trained (baseline vs. post)
	Control ($n = 19$)		Trained ($n = 40$)			Control ($n = 19$)		Trained ($n = 40$)				
	Mean	SEM	Mean	SEM	p	Mean	SEM	Mean	SEM	p		
Weight (kg)	43.5	2.4	41.6	1.1	0.469	44.9‡	2.6	42.7‡	1.1	0.465	0.17	0.16
Height (m)	1.31	0.1	1.31	0.0	0.982	1.34‡	0.0	1.34‡	0.1	0.952	0.07	0.07
BMI ($kg \cdot m^{-2}$)	24.8	0.9	23.8	0.4	0.359	24.9	1.0	23.6	0.4	0.260	0.02	0.08
Sitting height (cm)	71.8	0.6	71.1	0.6	0.477	72.3‡	0.6	72.0‡	0.6	0.494	0.20	0.23
Body fatness (%)	40.1	2.1	35.4	1.0	0.300	38.5	2.5	35.9	1.0	0.363	0.16	0.08
Fat mass (kg)	18.3	1.9	14.8	0.7	0.189	18.3	2.1	16.0	0.8	0.707	0.01	0.27
Fat-free mass (kg)	25.2	0.7	26.6	0.6	0.189	26.6	0.8	27.2‡	0.5	0.521	0.16	0.44
Triceps SKF (mm)§	23.1	1.3	21.4	0.6	0.218	22.9	1.3	21.6	0.7	0.350	0.04	0.05
Subscapular SKF (mm)§	24.3	2.0	23.0	1.2	0.670	23.9	2.0	23.4	1.2	0.840	0.05	0.05
$\sum$ SKF (triceps + subscapular) (mm)§	47.5	3.0	44.4	1.8	0.370	46.8	3.2	45.0	1.7	0.598	0.05	0.06

*BMI = body mass index; SKF = skinfold.

†Data from 7- to 9-year-old boys who were overweight/obese (control = 19 and trained = 40) submitted to a program of plyometric physical training (20 $min \cdot d^{-1}$, twice a week, during 12 weeks).

‡$p \leq 0.05$ refers to the comparison between baseline and postintervention in each group (control and trained). Effect size Cohen's *d* for control and trained group pre vs. posttraining.

§Log-transformed variables were used in the latter analysis. The *p* values refer to the comparison between control and trained in both baseline and posttraining.

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to perform all plyometric exercises in an explosive manner and there was no damage or injuries during the program of plyometric exercise. The program of plyometric training is described in Table 2.

Statistical Analyses

Exploratory data analysis was used to identify possible inaccurate information and the presence of outliers and to test the assumption of normality in all data distributions. Variables with skewed distributions were log-transformed (anthropometry and body composition). Descriptive statistics are presented as mean and standard error of mean. Intergroup (control × trained) differences were evaluated using independent sample *t*-tests. Intragroup differences (baseline × posttraining) were evaluated using paired Student's *t*-test. Physical fitness and gross motor coordination are presented as median, minimal and maximal value. The differences were evaluated by nonparametric tests, the intergroup (control × trained) differences were evaluated using Mann-Whitney *U*-test and the intragroup differences using Wilcoxon test. The interactions among groups at different times were analyzed using a 2-way analysis of variance, with group as independent factor (group) and repeated factor time (pre and postintervention). Effect size (Cohen's *d*) was used for both groups, control and trained, before and after intervention. Effect size has been defined as the degree at which the phenomenon is present in the study (6). The larger the effect size, the higher the degree at which the phenomenon under study manifests. Values below 0.2 are considered negligible, between 0.2 and 0.49 were interpreted as small effect; those between 0.5 and 0.79 as moderate effect; and values greater than 0.8 as large effect (6). All analyses were carried out using SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA) and statistical significance was set at $p \leq 0.05$.

Results

Table 3 shows the descriptive analysis of anthropometry and body composition of both groups before and after plyometric training. The groups were similar in age (T, 9.8 ± 0.9 years old; and C, 9.9 ± 1.1 years old; $p = 0.914$) and baseline physical characteristics (Table 2). Intergroup (control vs. trained) analysis at baseline and after plyometric training intervention showed that there was no difference between groups. After the period of 12 weeks, intragroup analysis (baseline and posttraining) showed that both groups presented gain in body weight, height, and sitting height, but only trained group showed an increase in FFM. The calculation of Cohen's *d* comparing baseline and postintervention for both groups show negligible/small effect size for all variables examined, except for fat mass and FFM, which showed a small effect for trained boys (Table 3).

For physical fitness and gross motor coordination, there were no differences between groups (control vs. trained) at baseline and after 12 weeks of plyometric training (Figure 1). Intragroup analysis showed that plyometric training improved handgrip strength, flexibility (sit and reach test), SLJ, agility (square test), 1-mile run test, and abdominal strength (curl-ups). For control group, these variables did not differ, except for curl-ups test (Figure 1C). The calculation of Cohen's *d* comparing control and trained groups at baseline and postintervention show negligible/small effect size for all variables of health-related physical fitness examined, except for stand long jump, which showed a large effect for trained group (Figure 1D).

For gross motor coordination, results were more pronounced in response to the protocol of plyometric physical training and trained boys showed improvement in all tests (Figure 2). Balancing backwards and one leg obstacle jumping showed a small effect size (d = 0.29 and 0.38, respectively) (Figures 2A, B). Lateral jump and jumping from side-to-side showed a large effect size ($d > 0.8$) (Figures 2C, D). Mean motor quotient of both groups was initially classified as "moderate motor disorder" (T, 79.8 ± 4.9; and C, 81.9 ± 6.1), but after plyometric training, T group mean got normal score (T, 101.2 ± 6.9; and C, 82.4 ± 5.1). For motor quotient, effect size Cohen's *d* was negligible for control group ($d = 0.02$), but large for trained group ($d = 1.02$).

Discussion

In the present study, we described the effects of 12 weeks of plyometric training on the anthropometry and body composition, health-related physical fitness, and gross motor coordination of 7- to 9-year-old boys who were overweight/obese. After 12 weeks, some anthropometric and body composition variables were changed in both groups, except FFM that increased only for trained group. These results are aligned with previous studies (16,19,21). However, boys who were overweight/obese submitted to this protocol of physical training showed improvements in the performance of most health-related physical fitness tests (flexibility, agility, manual strength, abdominal strength, and mile run test) and gross motor coordination. Interventions that have focused intensively on improvements on physical skills can be generally favorable to get success for children (9). These improvements can enhance the participation of children who were overweight/obese in sports and leisure activities. Our data suggested that children who were overweight/obese might engage on more extensively moderate/intense physical training program with a more efficient performance in specific exercise. It could be an important mechanism to avoid the high rate of nonadherence to physical program as seen for children who were overweight/obese (17). Our results add consistently to the evidence on primary intervention to improve motor performance during childhood.

We observed significant changes in body composition after 12 weeks of intervention for both groups. However, the gain of body weight, height, and sitting height can be related to a normal growth that is dependent on age as both groups presented the same increment (around 3 cm after 12 weeks).

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In fact, the calculation of the effect size showed that these differences were trivial, being statistically significant. Although this kind of physical training is not effective to reduce adiposity, trained boys showed an increased FFM. As previously observed, the increased the FFM is related to the specific type of exercise with stretch-shortening cycle movements (5,16,19). This type of exercise is predominantly anaerobic that can be confirmed by the lack of improvement in the $\dot{V}O_2max$. Because physical training improves the resting metabolic rate and increases FFM (8), plyometric training may be a valuable component of an integrated weight management program for children who were overweight/obese.

It was interesting to observe that curl-up performance also improved for control group after intervention with a small effect size. Our data indicate that the gain in the abdominal strength was time dependent in obese boys, in addition to gain in body weight, height, and sitting height. Supported by previous studies, plyometric training improved SLJ, flexibility, agility, and 1-mile run test (16,19). Improvements in the plyometric-induced performance can be more related to biomechanical parameters such as maximal isometric voluntary force, contractile and elastic musculoskeletal properties, musculotendinous stiffness, and rate of torque development in the quadriceps of children (15). It seems that training programs that include movements that are biomechanically and metabolically specific to the performance test may be more likely to induce improvements in selected performance measurements. Our findings showed that high-velocity plyometric movements that consist of a rapid eccentric muscle action followed by a powerful concentric muscle action are important for enhancing the rate of force development during jumping and sprinting. The main outcome related to obese boys is concerned to the possibility to engage in sports that needs explosive power and agility for the performance.

Although adiposity negatively influences both distance run time (by the excess weight that must be transported) and $\dot{V}O_{2max}$ per kilogram (acting as a metabolically inert load in the denominator), we observed improvement of the performance in the 1-mile test of trained group, but no effects on $\dot{V}O_2max$. According to previous studies, no more than 25% of the variance in endurance performance in children is actually related to cardiorespiratory capacity (1,25). However, body fat content and $\dot{V}O_{2max}$ together may explain only a portion of the variability in distance run times in children, suggesting that other factors (running economy, anaerobic fitness, motivation, skill) are important determinants of distance performance (25).

In the present study, trained children showed improvements in all gross motor coordination tests. Only for trained boys, there was seen an improvement on MQ such as they reach a normal score of 101.2 for age and gender (normal MQ = score 86–115) with a large effect size ($d > 0.8$). Plyometric training may also activate the neuromuscular system for the loads of sports exercise or different physical training (resistance, aerobic, etc) by activating additional neural pathways and enhancing to a greater degree the alert of the neuromotor system (19). This potential benefit may be particularly advantageous during the engagement on training when participants who were overweight/obese are learning how to perform correctly overloaded exercises. Although there is less emphasis on the development of motor skills during childhood, refined health-related physical fitness components and motor coordination acquisition are important to learn and to practice new movement skills and it can contribute to a physically active lifestyle.

We analyzed the effects of plyometric training individually for each boy to understand the degree of improvement. Our intervention probably provided an adequate magnitude of effort, because there was a small/moderate effect size to the benefit for physical fitness and moderate/large effect size for gross motor coordination in response to the intervention. Lateral plyometric jumps and squat jump can improve overall hip, knee, and ankle joint stability (16). In addition, single leg training (left or right) develops single leg strength, stability, and proprioception. These kind of jumps also help to improve balanced strength in the muscles of the lower limbs as seen in the improved performance of trained boys in the balance backward ($d = 0.29$), one-legged obstacle jumping ($d = 0.38$), lateral jump ($d = 1.19$), and jumping from side to side ($d = 0.76$) tests.

This is an important outcome because boys who were overweight/obese responded the same way for the demand of exercise. However, limitations of the present study included: absence of habitual physical activity measurements, and the lack of some behavioral parameter like diet or TV watching time. Our emphasis on using only an objective outcome measurement provided a rigorous test of the intervention.

Although there were no effects of plyometric training to reduce adiposity in obese boys, there was an increased FFM that can be related to improvements in motor performance of health-related physical fitness components. In addition, plyometric training improved the performance of all gross motor coordination tests and the motor quotient. This type of physical training may be particularly advantageous for children who were overweight/obese because it improves some health-related physical fitness components and motor coordination that can contribute to a physically active lifestyle.

Practical Applications

In the present study, a protocol of plyometric training improved health-related physical fitness and motor gross coordination of 7- to 9-year-old boys who were overweight/obese. Training program was conducted indoor at school gymnasiums and children were motivated to perform plyometric exercise during 20 minutes, twice a week, during 12 weeks. Our data showed that plyometric exercise with a progressive increment of intensity throughout the weeks

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induced a gain in FFM. The most pronounced effects were seen in the performance of health-related physical fitness tests as plyometric training improved SLJ, flexibility, agility, abdominal strength, and mile run test. Moreover, the performance in all KTK tests was improved after the weeks of training. Our results showed that this kind of training can be used combined with other kind of training to motivate children who were overweight/obese engaged in a physical exercise program.

Acknowledgments

This study was supported by National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES) and State of Pernambuco Science and Technology Support Foundation (FACEPE). The authors thank all children and their families for participating in this study. Authors declare no conflicts of interest.

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