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Plyometric training increases gross motor coordination and associated components of physical fitness in children.

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Original Article

Title: Plyometric training increases gross motor coordination and associated components of physical fitness in children.

Short title: Plyometric training in children

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ORIGINAL ARTICLE

Title: Plyometric training increases gross motor coordination and associated components of physical fitness in children.

Running title: Plyometric training responses on physical fitness and motor coordination

Abstract

There is only limited evidence to suggest that training during childhood produces greater adaptations than at other ages. The aim of this study was to examine the effects of plyometric training (12 weeks, twice/week, 20 min/day) on physical fitness (PF) and gross motor coordination (GMC) in schoolboys aged 7 to 9 years. A total of 116 boys were assigned to two groups: plyometric training group (PT,n=73) and control group (CG,n=43). The CG maintained their normal daily activities. The PT consisted of twice-weekly exercises on nonconsecutive days for twelve weeks under monitored and controlled conditions. PF (handgrip strength, standing long jump (SLJ), curl-ups, sit and reach, square-test, running speed, and 1 mile run test), GMC, Korper-koordinations-test fur Kinder (KTK), and body mass index (BMI) were assessed. The main results through a 2×2 (time×groups) repeated measures analysis variance demonstrated a significant time effect that improves PF and GMC according to the direction of the measure. A group effect was observed only in the abdominal strength test (CG=12.06% and PT=17.04%) and moving sideways (CG=11.1% and PT=12.4%) showing that independent of the group there was an improvement. A significant interaction effect (time×groups) was observed in the flexibility test (CG=-2.7% and PT=3.5%) and STJ (CG=3.1% and PT=18.5%), as well as jumping sideways (CG=16.3% and PT=17.4%) and overall GMC score (CG=9.8% and PT=15.9%), showing that gains in these variables were greater in the PT group. The results suggest that 12 weeks of PT improve components of gross motor coordination and health-related physical fitness in children.

Keywords: Motor Control, performance, exercise, strength

Highlights

- Plyometric exercise-induced adaptations is dependent on neuromotor plasticity of young children.
- Some physical fitness tests and gross motor coordination can be improved with age and plyometric training during childhood.
- Plyometric training is not intended to be a stand-alone exercise program and should be incorporated into a well-designed fitness program and gross motor coordination for children.

Introduction

Children develop motor skills by spontaneously engaging in regular physical activities, such as running and jumping in sport or recreational activities (Landry & Driscoll, 2012). Jump training is commonly associated with plyometric training, in particular with drills that stress the musculotendinous unit (Markovic & Mikulic, 2010; Taube, Leukel, & Gollhofer, 2012). These kinds of activities promote physical fitness that can be evaluated by the capacity to perform sit-ups, push-ups, long jump, and muscular strength and flexibility tests, as well as through cardiorespiratory fitness (Strong et al., 2005).

However, it is important to consider the precise timing of the exercise intervention as children present particular motor developments at each age (Lambert & Bard, 2005). Consistent with previous data, older children are, on average, more physically fit than younger children, which may be explained, in part, by increases in their body size, changes in their body composition, and their neuromuscular maturation (Santos et al., 2018). In horizontal jumps, taller children with more muscle mass, i.e., older children, tend to be favored when displacing their center of mass (Latorre Román et al., 2017). Furthermore, performance stability improves after the age of 7 while improvements in perception and reaction time are likely to occur after the age of 8 to 9 years (Lambert & Bard, 2005). These results suggest that the age of 7–9 years can be considered as a sensitive period for the development of motor performance, with potential adaptive changes in response to environmental factors.

Historically, plyometric training (PT) was considered unsafe for children because the ground reaction forces during jumps can result in musculoskeletal soreness, discomfort, and articular overloading (Kotzamanidis, 2006). However, recently there are a number of publications that have implemented plyometric training for children that would adhere to the training specificity principle (Behm et al., 2017). Besides, plyometric training can be safe and may improve a child's ability to increase movement, and power production provided that appropriate (Faigenbaum & Chu, 2001; Ramirez-Campillo et al., 2018; Ramirez-Campillo et al., 2019). This type of exercise can improve balance, jumping abilities, speed reaction, muscular strength, vertical jump height (Markovic, 2007; Markovic & Mikulic, 2010) and power production (Shah, 2012). In this context, D. G. Behm et al. (2017) reported in their meta-analysis that among other findings, power/plyometric training was more effective than strength training for improving youth jump height.

A previous study has shown that young boys (aged 10.6 years) performed plyometric training for 12 weeks (forward hopping, lateral hopping, shuffles, skipping, ladder drills, skipping, box jumps, low-intensity depth jumps) and presented improved speed, vertical jump, standing long jump, multiple 5-bound hopping leg strength, and agility (Michailidis et al., 2013). Likewise, an 8-week training period (plyometric plus balance exercises) improved leg stiffness and performance in 10-m sprints and shuttle run tests in 10-12-year-old children (Chaouachi, Othman, Hammami, Drinkwater, & Behm, 2014).

Although previous interventions have been implemented for children, there is no specific information about the effects of plyometric training on physical fitness and gross motor coordination. However, physically fitter children in terms of muscular strength (static and dynamic), agility, and speed tend to be more coordinated (Dos Santos et al., 2018) and children who were stronger and more agile presented steeper trajectories of gross motor coordination with age (Reyes et al., 2019). Addressing this shortfall in knowledge may be highly important within the context of physical education classes and the athletic training prescription in the young population.

Thus, the purpose of the present study was to examine the effects of plyometric training (12 weeks, twice/week, 20 min/day) on physical fitness and gross motor coordination in schoolboys aged 7 to 9 years. Our hypothesis was that plyometric training would improve performance in physical fitness and gross motor coordination tests.

Material and Methods

Participants

To conduct the study, a priori sample calculation was not performed. However, posteriori the statistical power was calculated and all the analyzes performed showed satisfactory power. The sample was then assigned to two groups: plyometric training group (PT, n = 73) and control group (CG, n = 43). All testing was conducted indoors in school gymnasiums on the floor to maintain a consistent surface and to eliminate environmental stimuli normally encountered outdoors. Facilities for PT were provided by the Laboratory of Kinanthropometry at UFPE and included: chronometers, four plyometric platforms with different heights (10, 20, 30, and 40 cm), and a gymnastic mattress. This study was approved by the Ethics Committee of the Centre of Health Science, Federal University of Pernambuco (CEPSH / CCS / UFPE, CAAE 04723412400005208). All the procedures adhered to the guidelines of the Declaration of Helsinki (www.wma.net/e/policy/b3.htm).

Experimental approach to the problem

One hundred and six children aged 7 to 9 years of age were selected by convenience from schools in the city of Vitória de Santo Antão, Pernambuco state, northeast Brazil. Written informed consent from parents or legal guardians was a criterion for the inclusion of each child in the study. The inclusion criteria were: (*i*) schoolboys aged 7 – 9 years registered in urban schools, (*ii*) resident in Vitoria de Santo Antão, (*iii*) no sport participation, (*iv*) no motor dysfunction and normal BMI-for-age according to the WHO Child Growth Standards (WHO, 2006). The exclusion criteria were: (*i*) having realized any exercise program during the period of the experimental approach, (*ii*) not having any physical problem that precludes realization of any test. There was no change in the routine school physical education classes, and no involvement or participation in sports for both groups (control and training) for at least six months before the intervention. Prior to data collection, all children participated in one introductory session and well-trained research assistants (physical education teachers, n = 5) demonstrated proper testing procedures and participants performed each test. Children were asked not to perform any vigorous physical activity on the day before or on the day of any study procedures. The plyometric training consisted of twice-weekly exercise sessions on nonconsecutive days for twelve weeks and was performed outside the physical education class schedule. Pre-testing was performed the week before the training period and post-testing was performed the week after the training period.

Measurements

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 0.1 cm using a portable stadiometer (Sanny, São Paulo, Brazil) with each subject's shoes off, feet together, and head in the Frankfurt horizontal plane (Lohman & Going, 2006). The body mass index (BMI) was calculated using the standard formula [weight (kg)/height^2 (m)]. Skinfold measurements (in millimeters) were taken on the right-hand side of the body at 2 sites (triceps and subscapular) using Lange skinfold calipers (Lange, Santa Cruz, CA, US). Skinfold data, with the skinfold equation of Lohman and Going (2006), were used to estimate the body fat percentage, as well as body fat and fat-free mass in kilograms.

Physical fitness

Physical fitness was assessed according to FITNESSGRAM (Research, 1999) and EUROFIT (EUROFIT, 1988) standardized test batteries. For the present study the following tests were chosen: (a) handgrip strength (measured independently in each hand), using a handgrip dynamometer (Saehan, Flintville, USA); (b) standing long jump (as a measure of the explosive power of the lower limbs); (c) curl-ups (as an indicator of dynamic muscle endurance of abdominal muscles); (d) sit and reach (as a measure of flexibility); (e) square test (as a measure of agility to complete a weaving running course [4x4 meter square] in the shortest possible time); (f) 20-meter running speed (to evaluate running speed in the shortest possible time), (g) time (minute) in the 1-mile run test as a putative indicator of relative maximal oxygen consumption (VO_2max), where time to run the distance was transformed to (h) VO_2max ($ml.kg^{-1}.min^{-1}$), using the regression equations from a previous study (Cureton, Sloniger, O'Bannon, Black, & McCormack, 1995).

Gross motor coordination

Gross motor coordination was evaluated with a standardized test battery for children (*Körper Koordination Test für Kinder* - KTK) (Kiphard & Schilling, 1974). The KTK includes assessment of the following items: (a) walking backward along a balance beam (WB); (b) jumping sideways over a slat (JS); (c) hopping for height on one foot (HH), and (d) moving sideways on boxes (MS). In the present study, the unweighted sum of the scores from the four KTK tests is reported as a measure of total GMC.

Data quality control

Data quality control was assessed by retesting 10% of the total sample in two distinct moments (test-retest) with a 15-day interval between test applications. Intraclass correlation coefficients (R) and respective 95% confidence intervals were used to estimate the relative reliability, the values of which were as follows: height, R=0.95 (95%CI: 0.85 to 0.98); weight, R=0.99 (95%CI: 0.98 to 0.99); handgrip strength, R=0.96 (95%CI: 0.89 to 0.98); standing long jump, R=0.67 (95%CI: 0.67 to 0.89); sit and reach, R=0.92 (95%CI: 0.78 to 0.97); curl-ups, R=0.95 (95%CI: 0.87 to 0.98); square test, R=0.75 (95%CI: 0.58 to 0.91); and 20m running speed, R=0.62 (95%CI: 0.49 to 0.88). For gross motor coordination, walking backwards, R=0.57

(95%CI: 0.25 to 0.81); hopping for height on one foot, R=0.49 (95%CI: 0.27 to 0.79); jumping sideways, R=0.69 (95%CI: 0.39 to 0.90); and moving sideways, R=0.69 (95%CI: 0.45 to 0.89).

Plyometric training

The plyometric training protocol consisted of twice-weekly exercise on non-consecutive days (Tuesday and Thursday) for twelve weeks under monitored and controlled conditions. The protocol included low intensity jumps followed by lateral jumps, squat jumps, left and right one-legged vertical jumps, and increasing levels of difficulty of the jumps. The daily training session was divided into three sections: warm-up (jogging at a self-selected comfortable pace followed by stretching for 3 min), training, and cool-down. Subjects exercised in small groups (i.e., 4 to 6 children) and an instructor to subject ratio of at least 1:3 was maintained. Each exercise session included 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 (i.e., two minutes) between exercises and sets. Whenever the participant fatigued and could not perform an exercise correctly, the exercise was interrupted. Subjects were encouraged to perform all plyometric exercises in an explosive manner and there was no damage or injuries during the program of plyometric exercise. A summary of the plyometric exercise program is described in Nobre at al. (Nobre et al., 2017).

Insert table 1

Statistical analysis

Normality was examined using the Shapiro–Wilk test and histogram inspections. Mean and standard deviation were calculated for both groups (control and plyometric training group) before and after the intervention. Since no statistically significant differences were found at baseline, data were analyzed as a single group (i.e., 7 to 9 years together). Within-group analysis was performed with mean percentage change ($\Delta\%$ = post-training/pre-training - 1), paired-sample t-test, and Cohen's *d* effect size. Cohen's *d* effect sizes were classified as trivial ($d< 0.20$), small (d = 0.20-0.49), moderate (d = 0.50-0.79), or large ($d> 0.80$) (Cohen, ,1988). A two-way mixed between-within analysis of variance was used to examine the main and interaction effects of time (pre *vs.* post) and group (control *vs.* plyometric training) for physical fitness and gross motor coordination tests, as well as the Bonferroni post hoc for multiple comparisons. Partial eta-squared effect sizes (η^2) for main and interaction effects were classified as small (η^2= 0.01–0.05), medium (η^2 = 0.06–0.14), or large (η^2>0.14) (Cohen, 1988). Partial η^2 can be defined as the ratio of variance accounted for by an effect and that effect plus its associated error variance within an ANOVA study (Brown, 2008). All analyses were carried out using SPSS version 20.0 (SPSS, Inc. Chicago, IL) and statistical significance was set at $p < 0.05$.

Results

Descriptive analyses of anthropometry and body composition are provided in table 3. No differences were found between control and plyometric training at baseline.

Insert table 2

Physical fitness and gross motor coordination values are presented in Table 3. Differences between groups at baseline were observed only in the moving sideways test of GMC. The within-group analysis of the control group showed that boys presented improved performance after 12 weeks in the abdominal strength and agility tests but worsened in the flexibility and 1-mile tests ($p<0.05$). In all motor coordination tests, except balance, performance improved after 12 weeks ($p<0.01$). All effect sizes in the control group were trivial to moderate.

The plyometric training group demonstrated improvement after 12 weeks in static muscular strength, abdominal and lower limb strength tests, as well as in agility and speed tests ($p<0.05$). Performance worsened only in the 1-mile test. All gross motor coordination tests and the overall KTK score improved after 12 weeks. The effect sizes in the plyometric training group were small to moderate in most tests, except for standing long jump, jumping sideways, and overall KTK score, which presented large effect sizes. A 2 × 2 (time × groups) repeated measures analysis of variance showed a significant time effect in most tests (Table 3; medium to large effect sizes), that represent the role of time of plyometric training in to improve different test, but the group effect was observed only in the abdominal strength test (CG=12.06% and PT=17.04%) and moving sideways (CG=11.1% and PT=12.4%) showing that independent of the group there was an improvement (Table 3; small and medium effect sizes, respectively). A significant interaction effect was observed in the flexibility test (CG=-2.7% and PT=3.5%; medium effect size) and standing long jump (CG=3.1% and PT=18.5%; large effect size), as well as jumping sideways (CG=16.3% and PT=17.4%) and overall gross motor coordination score (CG=9.8% and PT=15.9%), what it represents, regardless of the group or the time both groups have increased their performances (both small effect sizes) (table 3 and figure 1).

Insert table 3

Insert figure 1

Discussion

There are two ways to interpret the findings from the present study. Firstly, in the control group, independent of the exposure to PT, this group demonstrated improved performance in curl-ups and the square test, but reduced performance in the sit and reach and 1-mile. In the tasks of gross motor coordination, gains were observed in hopping for height, jumping sideways, moving sideways, and total gross motor coordination, except for walking backward.

During normal neuromotor development, the refinement of the cortical network improves motor abilities, speed, muscular strength, accuracy of movements, and motor coordination (Konczak, Jansen-Osmann, & Kalveram, 2003). In addition, the gain in body weight and stature with age can be associated with gains in muscular strength, standing long jump, agility, running speed, balance, and jumping. Since muscular strength increases progressively with both body mass and height, and this increase can be extended to the other variables (Lloyd, Oliver, Faigenbaum, Myer, & Croix, 2014), the present results could be considered a normal and expected adaptation.

However, when we consider the effect of plyometric training, our findings suggest that PT improves specific parameters of physical fitness (i.e., handgrip strength, curl-ups, standing long jump, square test, 20m running speed, and 1-mile, but not sit and reach (cm) or VO_2 (ml.kg^{-1}.min^{-1}) and the effect sizes ranged from small (*d*=0.24) to large (*d*=1.15) magnitudes. However, when seeing the results of VO2 (ml.kg-1.min-1) we need to consider that VO2 (ml.kg-1.min-1) and weight are related. Thus, as we estimated the VO2 (ml.kg-1.min-1) using the regression equation, from a previous study (Cureton et al., 1995), is necessary to observe that if the children change their weight as expected, they change the VO2 (ml.kg-1.min-1), too.

In addition, PT improved all tasks of gross motor coordination (effect size range *d*=0.43 to *d*=1.10). Our data extend previous studies that observed improvements in sprinting, jumping ability, strength, running economy, and agility in children in response to plyometric exercises (Chaouachi, Othman, Hammami, Drinkwater, & Behm, 2014; Chaouachi et al., 2017; Hammami, Granacher, Makhlouf, Behm, & Chaouachi, 2016; McKay & Henschke, 2012; Michailidis et al., 2013). This was consistent with our hypothesis that plyometric training would improve performance in physical fitness and gross motor coordination tests.

Interventions that focused intensively on improvements in physical skills are generally favorable to demonstrate success for children (Johnson, Salzberg, & Stevenson, 2011). Improvements in plyometric-induced performance could 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 (Grosset, Piscione, Lambertz, & Pérot, 2009). 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 (Behm et al., 2017; Nobre et al., 2017).

The second and more important way to interpret our findings is related to the "main effect" of PT. Thus, it is possible to observe that the effects were specifically related to time in handgrip strength, standing long jump, square test, 20m running speed, and 1-mile, showing that twelve-weeks are sufficient to promote alterations in these variables. However, only curl-ups had a time and group effect. Training-related mechanisms that could explain the main effect include changes in the stiffness of various elastic elements of the muscle-tendon complex, transition to type II muscle-fiber, according to the passage through different ages, increases in the magnitude of muscle contractility, increased muscle size, altered fascicle angle, enhanced motor unit recruitment and discharge rate, greater inter-muscular coordination, higher stretch-reflex excitability, enhanced neural drive to agonist muscles, and better utilization of the stretch-shortening cycle (Markovic & Mikulic, 2010). However, a lack of clarity in how some of these mechanisms are manifested (Markovic & Mikulic, 2010), in addition to the confounding effects of maturation-related physical changes (Lloyd, Oliver, Hughes, & Williams, 2011), mean that explanations of the effects are speculative. In this context, Moran et al., reported that it seems PT is moderately effective during childhood but seems to be less so around the time when growth achieves its greatest rate of progression (Moran et al., 2017).

There are few studies, that analyzed the effects of PT in gross motor coordination. However, in our findings, a main effect of time was observed in all parameters of gross motor coordination (i.e., walking backward, hopping for height, jumping sideways, moving sideways, and total gross motor coordination) as well as which, only moving sideways had a time and group effect. However, a study realized by Nobre et al. (2017), showed in overweight/obese children (7 to 9 years old), that a protocol of plyometric training improved health-related physical fitness and motor gross coordination.

Although we could not find previous evidence of PT influencing motor coordination in later childhood, we speculate that the relationship between physical fitness and motor coordination tasks of KTK may be associated and seems to be the bridge that relates the effects of PT in both variables. These issues become even more relevant because it has been pointed out that children's motor development has also been associated with health-related habits and behaviors (Robinson et al., 2015). It is known that the interval from 6 to 9 years is sensitive for the refinement of a variety of fundamental movement skills and that development of health-enhanced behaviors may persist into adolescence (Gallahue, Ozmun, & Goodway, 2012).

The present study showed that the effects of plyometric training are aligned with previous studies that observed a significant training outcome regarding the jumping ability, agility, running speed, and gross motor coordination values from pre- to post-training (Chaouachi et al., 2014; Chaouachi et al., 2017; Hammami et al., 2016; Michailidis et al., 2013). However, in this context, it´s important to consider the changes that occurred regardless of the involvement in PT because some children of the CG experienced changes that possibly were mediated by the over the different ages. Exercise interventions are complex and need to respect at least two principles: over-loading and specificity. The progressive overload allows optimization of the adaptation of various systems in relation to monotonous training (Bompa & Buzzichelli, 2015). In this perspective, our protocol of plyometric exercise started with five different jumps, with a total jump of fifty (i.e., 10 sets *x* 5 jumps sets) and increased 10 jumps in every three sessions throughout the weeks to follow the principle of overload (Johnson et al., 2011). The mixing of jumps during an individual session of training was implemented to maintain a high degree of motivation in the children to perform plyometric training. Indeed, in the present study, all the trained boys performed the 12 weeks of training and the variation in jumps could have played an important role in keeping the children engaged in the program of physical training, especially the young children.

Another principle of the training is the specificity which, from a physiological perspective, noticeably improves the function that is being trained at the expense of the function that is not determinant for that training (Kotzamanidis, 2006). The outcomes of this study were an improvement in physical fitness and gross motor coordination variables. Although the principle of specificity of the training must be used in order to understand exercise-induced adaptations, jumping may be considered a specific exercise for the development of acceleration because of the similar contact times of jumping and sprinting during the initial acceleration phase (Behm & Sale, 1993; Behm et al., 2017; Dahab & McCambridge, 2009; Markovic & Mikulic, 2010). This mechanism explains the improvement in all motor performance variables instead of being restricted to those related to standing long jump or running speed.

Movements performed by children, primarily balance, walking, kicking, and running are spontaneous and assume stereotyped patterns (Lambert & Bard, 2005). The capability to control goal-oriented movements within this scenario is a crucial challenge for sensorimotor development (Lambert & Bard, 2005). In addition, the execution of plyometric training is based on the integration of proprioception, vestibular function, and vision, necessary to maintain control of the body in movements that require synergetic functioning of the cerebellum, spinal cord, and skeletal muscle innervation (Achiron & Kalron, 2008).

This study is not without limitations. First, the absence of habitual physical activity measurements, and the lack of some behavioral parameters like diet or TV watching time. Second, GMC and physical fitness were assessed with the KTK, Fitnessgram and Eurofit battery and these tests have several tasks where is expected to have an inter-individual variability, yet it has been consistently used showing wide applicability. Our emphasis on using only one objective outcome measurement provided a rigorous test of the intervention. However, these results are consistent with the executive function hypothesis that assumes that exercise training stimulates a significant rise in gray matter volume and a prolonged increase in myelination and connectivity between age 8 and pre-adolescence in the pre-frontal and frontal cortex (Kopp, 2012; McKay & Henschke, 2012; Moran et al., 2017). The findings of this study about motor performance in physically trained and control boys highlight the need to consider the time to start physical training during childhood. This issue should be addressed in future research and the mechanism should be studied. In particular, in the field of sports science and physical education, developmental features should be accounted for in the decision to plan physical exercise protocols to respect the neuromotor plasticity.

Conclusion

In summary, we found that a protocol of plyometric training with a progressive increment of intensity during twelve weeks improves PF and GMC according to the direction of the measure. A group effect was observed only in the abdominal strength test and moving sideways showing that independent of the group there was an improvement. A significant interaction effect was observed in the flexibility test and standing long jump, as well as jumping sideways and overall GMC score. In addition, the findings of this study suggest that to increase children's GMC levels, physical education and intervention programs should focus on increasing children's physical fitness (namely muscular strength, running speed, and agility). Paying attention to these modifiable fitness components may translate into increases in children's health status, as well as reducing the frequency of children with low motor coordination. This information is useful and will most certainly help physical education teachers, parents, and sports coaches to better understand children's GMC and use these putative sensitive periods to enhance the efficiency of their educational programs.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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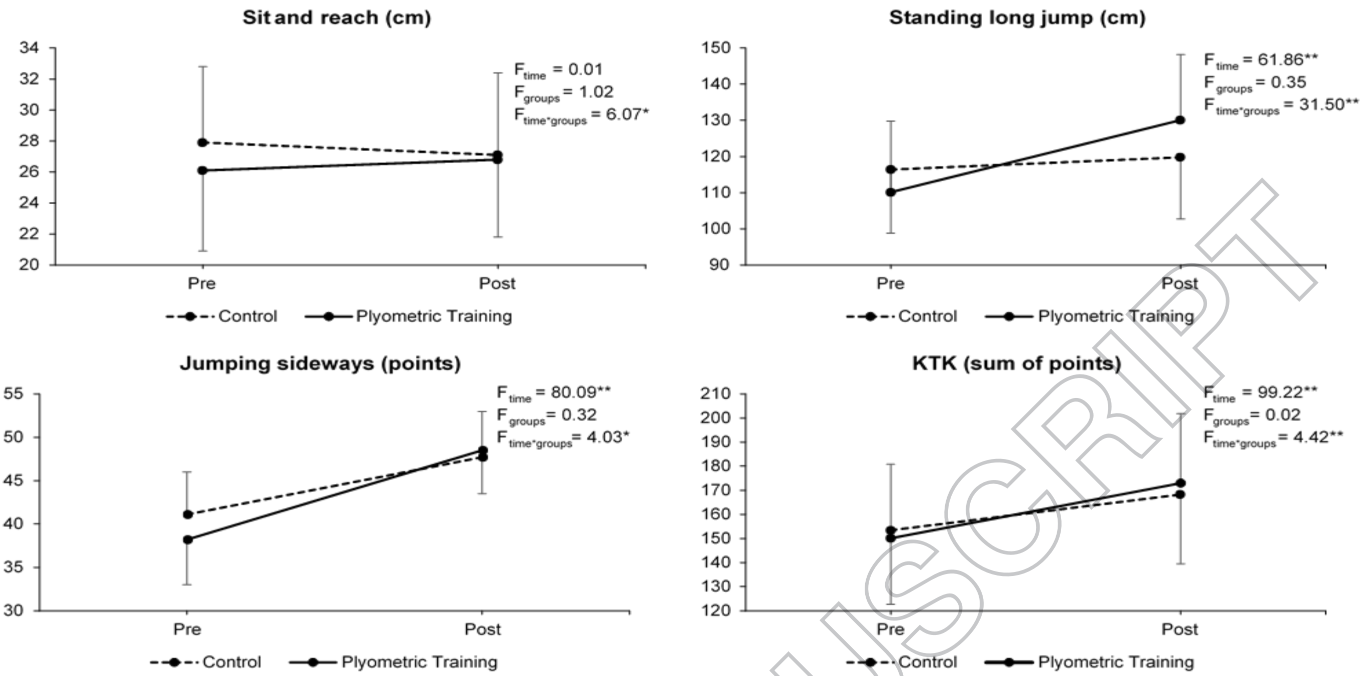

Figure 1. Effects of plyometric training on different tests of physical fitness (sit and reach and standing long jump) and gross motor coordination (jumping sideways and sum of points of KTK).

Table 1. Description of the protocol of plyometric training.

Week	Session	Sets	Jumps per set	Total jumps	Type of Jumps
1st	1	10	5	50	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height; (5) Decreasing height
	2				
2nd	3				
	4	12	5	60	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height; (5) Decreasing height; (6) Increasing height + Squat jump
3rd	5				
	6				
4th	7	14	5	70	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height; (5) Decreasing height; (6) One-legged jump (left); (7) One-legged jump (right)
	8				
5th	9				
	10	16	5	80	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height; (5) Decreasing height; (6) One-legged jump (left); (7) One-legged jump (right); (8) Increasing height + Squat jump
6th	11				
	12				
7th	13	18	5	90	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height*; (5) Decreasing height; (6) One-legged jump (left); (7) One-legged jump (right); (8) Increasing height + Squat jump
	14				
8th	15				
	16	20	5	100	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height*; (5) Decreasing height*; (6) One-legged jump (left); (7) One-legged jump (right); (8) Increasing height + Squat jump
9th	17				
	18				
10th	19	22	5	110	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height*; (5) Decreasing height*; (6) One-legged jump (left)**; (7) One-legged jump (right)**; (8) Increasing height + Squat jump
	20				
11th	21				
	22	24	5	120	(1) Lateral jump; (2) Squat jump; (3) Different height; (4) Increasing height*; (5) Decreasing height*; (6) One-legged jump (left)*; (7) One-legged jump (right)*; (8) Increasing height + Squat jump
12th	23				
	24				

* Repeated once; ** Repeated twice

Table 2. General characteristics of experimental groups at baseline.

	Control (n=40)	**Plyometric Training (n=64)**	***t***	***p***	***d***
Age (years)	7.9±0.7	7.9±0.9	-0.13	0.90	-0.03
Body mass (kg)	26.7±4.6	26.3±3.8	0.57	0.57	0.11
Stature (cm)	128.1±7.3	127.8±7.0	0.22	0.83	0.04
BMI (kg/m^2)	16.2±1.5	16.0±1.3	0.61	0.54	0.12
Triceps SF (mm)	9.9±3.7	10.4±3.8	-0.62	0.54	-0.12
Subscapular SF (mm)	6.3±2.3	6.5±2.6	-0.36	0.72	-0.07
Sum of SF (mm)	16.3±5.7	17.0±5.7	-0.63	0.53	-0.13
Body fat (%)	14.9±5.0	15.6±5.0	-0.67	0.50	-0.14
Body fat (kg)	4.1±1.9	4.2±1.8	-0.22	0.83	-0.05
Fat free-mass (kg)	22.6±3.2	22.1±2.7	0.96	0.34	0.19

"*t*" represents a t-test

Table 3. Mean and SDs for dependent measures (physical fitness and gross motor coordination) of control and plyometric physical training at pre- and post-training evaluation and main and interaction effects.

Variables	Groups										Main effect				Interaction effect	
	Control					Plyometric Training					Time		Group			
	Pre	**Post**	**Δ%**	***t***	***d***	**Pre**	**Post**	**Δ%**	***t***	***d***	**F**	**η²**	**F**	**η²**	**F**	**η²**
Physical fitness																
Handgrip strength (kgf)	10.3±2.8	10.9±3.6	5.24	-1.95	0.17	9.8±2.9	10.6±3.0	7.35	-3.77**	0.24	14.95**	0.13	0.34	0.00	0.32	0.00
Sit and reach (cm)	27.9±4.9	27.1±5.3	-2.75	2.19*	0.16	26.1±5.2	26.8±5.0	3.57	-1.68	0.18	0.01	0.00	1.02	0.01	6.07*	0.06
Curl ups (n/min)	20.8±8.5	23.4±6.4	12.06	-2.59*	0.30	18.0±7.5	20.5±9.2	17.04	-2.48*	0.36	11.22**	0.10	3.86*	0.04	0.00	0.00
Standing long jump (cm)	116.4±17.6	119.8±17.1	3.18	-1.51	0.22	110.1±19.7	130.1±18.1	18.51	-10.57**	1.15	61.86**	0.38	0.35	0.00	31.50**	0.24
Square test (s)	7.8±0.5	7.5±0.6	-3.32	2.41*	0.48	7.8±0.6	7.6±0.6	-3.23	3.19**	0.41	15.23**	0.13	0.47	0.00	0.01	0.00
20m running speed (s)	4.9±0.3	4.8±0.3	-0.94	1.12	0.13	4.9±0.4	4.8±0.4	-2.19	2.70*	0.27	6.50**	0.06	0.03	0.00	1.46	0.01
1- mile (min)	11.4±2.0	12.2±2.1	6.47	-2.66*	0.37	11.6±1.7	13.0±2.0	12.85	-5.48**	0.79	29.92**	0.23	2.56	0.02	2.75	0.03
VO_2 (ml.kg^{-1}.min^{-1})	46.6±2.2	46.4±2.4	-0.30	0.59	0.06	46.3±1.7	46.6±3.0	1.64	-0.64	0.25	0.00	0.00	0.03	0.00	0.67	0.01
Gross motor coordination																
WB (points)	36.7±13.3	39.0±11.3	6.45	-1.36	0.20	37.3±12.3	41.9±11.3	13.23	-4.35**	0.43	13.22**	0.11	0.66	0.01	1.37	0.01
HH (points)	37.7±9.0	39.7±7.7	4.96	-2.30**	0.23	39.7±9.7	43.5±9.3	10.22	-5.31**	0.44	25.96**	0.20	2.81	0.03	2.43	0.02
JS (points)	41.1±10.1	47.7±10.8	16.33	-3.77**	0.65	38.2±10.1	48.5±9.5	27.42	-10.08**	1.10	80.09**	0.44	0.32	0.00	4.03*	0.04
MS (points)	37.9±6.2$^{\#}$	41.9±8.4	11.11	-2.99**	0.59	34.9±6.3	39.1±5.3	12.49	-5.24**	0.76	31.36**	0.24	7.27**	0.07	0.01	0.00

TGMC (sum of points)	153.4±23.8	168.3±27.0	9.87	-4.61**	0.61	150.1±30.7	173.0±28.8	15.93	-10.32**	0.85	99.22**	0.49	0.02	0.00	4.42*	0.04

Note: WB, walking backward; HH, hopping for height; JS, jumping sideways; MS, moving sideways; TGMC, total gross motor coordination; "*t*" represents a t-test; # difference at baseline; *p<0.05, **p<0.01