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Effects of resistance training on jumping performance in pre-adolescent rhythmic gymnasts: a randomized controlled study

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Abstract

The aim of this study was to determine the effectiveness of two different resistance training programs on lower limb explosive and reactive strength in young female athletes. Fifty seven rhythmic gymnasts were randomly assigned to unspecific resistance training with dumbbells (12 repetition maximum squats) (n=19; age=12.0±1.8 years) or to specific resistance training with weighted belts (6% of body mass; n=18; age=11.9 ± 1.0 years). Squat jump test, counter movement jump test, hopping test, flexibility of the hip, and anthropometric measures were assessed before and after six weeks training. The main result was that both unspecific resistance training and specific resistance training protocols positively affected the jumping performance, with an increase of the lower limb explosive strength of 6-7%, with no side effects. Counter movement jump flight time increased significantly ($p<0.01$) while hopping test ground contact time significantly decreased ($p<0.01$). No significant differences were detected among groups for flexibility, body mass, calf and thigh circumferences. Therefore, six weeks of resistance training that integrates different elements of rhythmic gymnastics training enhance jumping ability in young female athletes.

Key words

Adolescents, muscle strength, stiffness, flexibility, jumping, weighted belts, dumbbells.

Key to abbreviations

RM = repetition maximum
SJ = squat jump test
CMJ = counter movement jump test
HT = hopping test

Introduction

Over the past decades resistance training, that is a method to improve muscular strength by increasing the ability to resist force applied through free weights,

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machines, or the person's own body weight, was not often recommended for young athletes by the scientific community because of a presumed risk of injuries associated with this type of exercise. Recent findings, conversely, have demonstrated that resistance training can be an effective tool to increase strength in children and adolescents, when appropriately prescribed and supervised. (Payne et al., 1997; Faingenbaum et al., 2009; Harries et al., 2012). The current position of the National Strength and Conditioning Association (NSCA) is that regular resistance training is safe for young people and plays an important role in growth and maturation during pediatric years (Malina, 2006). Moreover, resistance training reduces the likelihood of sport-related injuries, improves motor skill and facilitates weight control.

Explosive muscular power, that is the ability to generate muscular work in a short time, and the rate of force production are the basis for most sport actions (Kraemer and Newton, 1994). Explosive strength, floor reaction time, flexibility and anthropometric features account for 41% of the success in performing rhythmic gymnastics (Miletic et al., 2004). In this discipline, resistance training is needed for good leaping ability, although a low degree of muscle hypertrophy is an important prerequisite in order to be thin and "lightweight" (Di Cagno et al., 2008). The addition of resistance training to the traditional dynamic strength conditioning (i.e. training to develop powerful movements) may increase the rate of force development of gymnasts (Young et al., 1998) and consequently improve performance. Motor performance skill tests such as vertical jumps are commonly used to assess changes in muscular strength and power. Thus, the aim of this study was to determine the effectiveness of two different resistance training programs on lower limb explosive and reactive strength (defined as a concentric contraction following a rapid eccentric contraction resulting in a greater concentric force output), and to assess if such protocols induce changes in flexibility, body mass and muscle circumference. A contraction is "concentric" when it results in shortening of a muscle, as when lifting an external load or accelerating a body part; it is "eccentric" when exerted in the presence of a resistive force with eventual elongation of a muscle, as when incompletely contrasting an external load or decelerating a body part. The study was designed to test the hypothesis that a specific resistance training may be more effective for young elite rhythmic gymnasts than an unspecific resistance training protocol.

Subjects and methods

Experimental strategy

This study followed a repeated measures design to assess the effectiveness of two different resistance training protocols, i.e. with dumbbells or belts, on the lower limb explosive and reactive strength of young female rhythmic gymnasts aged 10-13 years.

Squat jump (SJ), counter movement jump (CMJ), hopping test (HT), flexibility of the hip and anthropometric measures were assessed before and after six weeks of training program.

Subjects

Fifty-seven female rhythmic gymnasts, aged between 10 to 13 years, competing at the same technical level, with at least two years of sport participation, volunteered to take part in this study. Athletes were randomly assigned to unspecific resistance training (n = 19; age = 12.0 ± 1.8 years; body mass index = 18.4 ± 2.2 kg) or to specific resistance training (n = 18; age = 11.9 ± 1.0 years; body mass index = 17.8 ± 1.5 kg). The training groups were determined using a randomization list, generated by a random number generator. Order assignments were placed in sealed, opaque, consecutively numbered envelopes, and were concealed by one of the study investigators involved in the randomization process. Both groups maintained their own habitual sport practice. All participants except three had not had menarche. None of the subjects had training experience using resistance training equipment before the start of the study. Athletes, parents and coaches were informed about the nature of this project, and parents of the underage athletes gave their written consent for the study before data collection. The study was designed according to the Declaration of Helsinki and was approved by the local ethics committee.

Training

The resistance training programme of the experimental groups was organized as follows: for 6 weeks, the first group of gymnasts followed an unspecific, moderate load/high repetition resistance training program with dumbbells (Faingebaum et al., 2001) and the second group performed a gymnastics specific strength training using weighted belts (Mersh and Stoboy, 1989), as follows.

One -repetition maximum (1-RM) represents the maximum amount of weight that a subject can lift in a single execution of a given exercise, and is a widely accepted valid dynamic strength measure (Horvat et al., 2003; Kramer et al., 2006). The intensity of an exercise can be expressed as percentage of 1-RM (e.g. 70% 1-RM, that is the 70% of maximum amount of weight that subject can lift) or as multiple of this measure (e.g. 6-RM, that is the maximum weight that a subject can lift to repeat a given exercise 6 times). In this study, 12-RM squat (the maximum amount of weight that an athlete could lift to repeat a squat 12 times) was evaluated for each athlete before beginning, after three weeks, and at the end of the experimental training.

The first group of gymnasts, after warm-up, performed 3 sets of 12-RM squat movements with dumbbells. Rest periods were 45 sec between exercises and 2 min between sets (Faigenbaum et al., 2006; Mangine et al., 2008).

The second group, after warm-up, followed a strength training protocol for 15 min using weighted belts set at 6% body mass (Xtreme Worldwide Athletic Equipment), twice a week, on non consecutive days (Faingebaum et al., 2001). The protocol consisted of three repetition of ten dynamic exercises, progressing from low- to moderate-intensity (Table 1). Gymnasts were instructed to perform the resistance training protocol as fast and as explosively as possible. Approximately one minute rest was allowed after the three repetition of each exercise (Faigenbaum et al., 2006).

Each group was trained with the instruments to be used, before starting the experimental sessions.

Testing procedures

All the subjects were assessed before and after six-week resistance training for lower limb explosive strength, by jumping tests, and for stiffness, by measuring flex-

Table 1 – Rhythmic gymnastics specific strength conditioning protocol for lower limbs with weighed belts.

1. Running.
2. Lateral shuffle. Move laterally quickly without crossing feet.
3. Running with explosive repetition velocities.
4. Walking with limbs flexed / flexed legs alternate with walking with limbs extended / stretched legs up on toes.
5. Backward lunge. Move backwards by reaching each leg as far back possible.
6. Power skip. Rapidly skip forward, elevating body as high as possible.
7. Heel ups. Rapidly kick heels towards buttocks while moving forward
8. Lunge walks. Lunge forward with alternating legs while keeping torso vertical.
9. High - knee skip. Emphasize knee lift and arm swing while moving forward in different directions.
10. Stretched leg jumps alternated with leg tuck jumps with legs to the chest.

ibility. Anthropometric data was also collected to evaluate variations in body mass or segmental circumferences.

Jumping tests

The two groups of gymnasts, in the testing sessions, performed three vertical jumps, three times each jump, in the following order: Squat Jump (SJ), Counter-Movement Jump (CMJ) and Hopping Test (HT). Thirty seconds rest was given between the trials of each jump, and the maximum value was considered. A SJ consists in a maximal vertical jump, starting with the knees bent a 90°, with the hands on hips throughout the exercise. A CMJ consists in a maximal vertical jump with the hands on hips, starting with a preliminary counter movement (in standing position, the subject flexes the knees to 90° and then jumps). The SJ and CMJ flight time was recorded and used to estimate the height reached during the jump. According to Bosco et al. (2002), the height of SJ and CMJ is a way to assess the explosive lower limb power. HT is a series of seven continuous jumps with free arms, with a small amplitude counter movement and a short ground contact time. If these requirements were not met, the trial was repeated. HT was used to assess the leg stiffness, which is inversely correlated with the contact time during the test. Ground contact time and flight time were measured by Optojump (Microgate, Bolzano, Italy). This system has a high reliability (range 0.88-0.98 as calculated by Interclass Correlation Coefficient: Di Cagno et al., 2008). All measures, pre and post, were taken by the same researchers who were blind to the experimental condition of athletes. The athletes were accustomed to the test by practicing several jumps before the test ones.

Flexibility measurements

Flexibility parameters were assessed by measuring the active range of motion of the hip joints. The range of active hip abduction (A), hip external rotation (ER), and hip internal rotation (IR) were measured at baseline and at the end of the experimental training. Angular displacement was measured using inclinometer (a circular, fluid filled goniometer; Baseline® AcuAngle Inclinometer, Kom Kare Company, Ohio, Usa) which measures the value in angular degrees through a gravity device (MacDougall et al., 1991). Inclinometer reliability was examined in the first 10 athletes. An Intraclass Correlation Coefficient of 0.98 indicated a high level of reliability. Gymnasts were instructed before testing on how to perform the required movements.

To measure hip abduction, athletes were positioned lying on the floor with the body left side, with the lower limbs extended. For internal and external rotation, athletes were positioned prone in a neutral position, with the arms aligned with the trunk, the face down, and the knee maintained at 90° flexion. After zeroing the inclinometer, gymnasts were asked to perform maximal active movements. Each movement was measured until the point where no further motion could occur without pelvic movement. Each movement was performed three times and if the above mentioned requirements were not met the trial was repeated.

Anthropometric data were obtained from each participant using standard data collection procedures and standard laboratory scale (Lohman et al., 1988). Body mass and height were measured using a calibrated balance scale and stadiometer, respectively. The thigh and calf circumferences were measured at the level of the maximal thigh and calf girth. A well-trained anthropometrist took the anthropometric measurements and was assisted by a recorder who was familiar with the specific procedures. All measurements were recorded three times and the maximum value was considered for analysis.

Statistical Analysis

Descriptive statistics, *i.e.* mean ± standard deviation (SD), and percentage differences in strength, flexibility and anthropometric data were calculated. Unpaired samples *t*-test was used to compare the study groups at baseline. Data were subjected to repeated measures 2×2 analysis of variance (ANOVA) to assess differences within (pre and post) and between groups for each variable. When a significant main effect or interaction was found, a simple effect analysis was performed. Differences between groups were analyzed using *t*-test for unpaired samples, while differences within groups were analyzed by *t*-test for paired samples. The α level was set at $P \leq 0.05$ and the analyses were conducted using SPSS 16.0 statistical package (SPSS, Inc., Chicago, IL).

Results

All the gymnasts completed the study and no injuries or health complains were reported. There were no differences in baseline strength or flexibility between the two groups.

ANOVA showed significant interaction between group and training for the flight time of HT ($F_{1.24} = 4.3$; $p < 0.05$). A significant difference was found for HT flight time between unspecific and specific training ($p < 0.01$) with higher scores after unspecific training. The HT ground contact time significantly decreased after each kind of resistance training ($F_{1.24} = 10.4$; $p < 0.01$) and a significant interaction was found between training and group ($F_{1.24} = 18.9$; $p < 0.05$). The effect of training on CMJ flight time was significant ($F_{1.24} = 24.1$; $p < 0.01$), whereas no interaction was demonstrated between training and group. A significant effect of training was detected on SJ flight time ($F_{1.24} = 6.5$; $p < 0.05$), whereas no significant difference was found between groups.

Table 2 – Mean, standard deviation (SD) and percentage variation (Δ) of anthropometric, flexibility and jump parameters between pre- and post-training.

	Unspecific weight training		Δ (%)	Specific weight training		Δ (%)
	PRE (mean ± SD)	POST (mean ± SD)		PRE (mean ± SD)	POST (mean ± SD)	
HT flight time (ms)	412.9 ± 68.4	441.7 ± 44.2[#]	+7.0	420.0 ± 35.1	395.3 ± 46.5	- 5.9
HT ground contact time (ms)	230.4 ± 32.1	238.7 ± 29.8[##]	+3.6	256.0 ± 35.3**	199.9 ± 20.5	-21.9
SJ flight time (ms)	427.1 ± 35.3	440.1 ± 28.0	+2.7	410.4 ± 41.6	421.5 ± 28.4	+ 2.7
CMJ flight time (ms)	449.7 ± 34.5**	481.3 ± 30.8	+7.0	457.2 ± 30.6**	485.0 ± 33.8	+ 6.1
Hip Abduction (°)	86.2 ± 10.6	87.3 ± 11.7	+1.2	90.7 ± 12.1	78.9 ± 11.1	-13.0
Hip external rotation (°)	42.4 ± 8	44.1 ± 6.6	+4.0	45.6 ± 6.9	44.5 ± 6.3	- 2.4
Hip internal rotation (°)	46.0 ± 10.3	42.8 ± 8.2	-6.9	48.1± 6.5*	43.2 ± 4.8	-10.0
Body mass (kg)	40.7 ± 9.4	41.8 ± 9.4	+2.8	36.5 ± 6.7	36.7 ± 7.0	+ 0.5
Thigh circumference (cm)	42.5 ± 4.6**	44.8 ± 6.2	+5.4	40.6 ± 2. 3**	43.9 ± 3.7	+ 8.1
Calf circumference (cm)	30.3 ± 3.2	30.7 ± 3	+1.2	29.4 ± 1.8	29.6 ± 2.8	+ 0.9

* $p < 0.05$ vs. post-training.
** $p < 0.01$ vs. post-training.
[#] $p < 0.05$ vs. specific weight training.
[##] $p < 0.05$ vs. Specific weight training.

There were no significant differences between groups for the three flexibility measurements, body mass, or calf and thigh circumferences. 2×2 repeated measures ANOVA showed significant differences between pre- and post-training only for hip internal rotation ($F_{1.24} = 5.2$; $p < 0.05$). Thigh circumference increased significantly ($F_{1.24} = 27.2$; $p < 0.01$) in both groups with no difference between groups. No significant body mass increase was observed after either experimental protocols. Results of paired sample *t*-test post hoc analysis are showed in Table 2.

Discussion

The main finding of this study was that both tested resistance training protocols affected positively the jumping performance in young rhythmic gymnasts, with an increase of 6-7% in lower limb explosive strength and with no side effects. Despite the inherent limitation of the study because of lack of a non-exercising control group, the results allowed an objective, quantitative comparison between the two training protocols tested.

Our results are in agreement with other studies which reported statistically significant increases in explosive strength ranging from 5% to 24% as assessed by vertical jumps, after resistance training (Soh et al., 2007; Gabbet et al., 2008; Mujika et al., 2009; Alves et al., 2010). In this study, CMJ flight time, which assesses the explosive lower limb power (Bosco et al., 2002), significantly improved after both unspecific and specific training, while the HT flight time, which assesses leg stiffness, improved only after unspecific training. In previous studies, it had been shown that a lack of strength in athletes was a consequence of inadequate training load, volume, duration and progression (Siegel et al., 1989; Dayne et al., 2011). Coherently, our study demonstrated that load increase was able to improve the jumping performance in rhythmic gymnasts. No injuries occurred to gymnasts through the whole training duration, as it had been observed in other studies (Faingenbaum et al., 2009).

The HT ground contact time decreased only after specific training, due to the high plyometric (*i.e.*, jump training) regimen that characterized this protocol. Shorter ground contact time in HT is a talent identification parameter for leaping ability, and stiffness is highly correlated with flight time and good execution of the technical leaps in rhythmic gymnastics (Di Cagno et al., 2008). Several studies have recognized that the best results in sport are obtained using training protocols which are as specific as possible to the demands of the sport activity (Thompsen et al., 2007). Specific training is characterized by dynamic movements and is designed to elevate core body temperature, enhance motor unit excitability, improve kinaesthetic awareness, maximize active range of motion, and improve technique by reinforcing critical motor programs (Robbins and Docherty, 2005). Consequently, although the results of this study gave indication in favour of both resistance training methodologies to improve explosive lower limb power and stiffness, specific training appeared to be preferable as it increased reactive strength. The benefits of this kind of training were recognized in several investigations (Kubo et al., 2007), especially for intramuscular coordination (Burkett et al., 2005). However, the unavoidable continuation of the athletes' habitual sport activity during the intervention period made it difficult to determine the independent contribution of each resistance protocol to the improvement in muscular power.

In accordance with previous studies, the gymnast calf circumferences did not increase after either kind of training. The training-induced strength gain in preadolescents is, in fact, more related to neuromuscular activation and coordination rather than muscle hypertrophy (Ozmun et al., 1994; Malina, 2006). Without adequate levels of circulating testosterone to stimulate increase in muscle size, pre-pubescent subjects experience more difficulty in increasing their muscle mass with a resistance training program (Vrijens, 1978). In contrast, thigh circumferences significantly increased after both unspecific and specific training, with no significant differences between the two protocols (Malina and Katzmarzyk, 2006). A low level of free fat mass is a requirement for competitive female aesthetic sports. We hypothesize that the chosen loads were too high for the sample group. Resistance training programs with high repetition regimen, using weighted belts at the 2% of body mass, might probably induce less thigh circumference increase (Campos et al., 2002).

Rhythmic gymnastics requires athletes with high flexibility and a good compromise between strength and flexibility is advisable for high quality performance (Douda et al., 2002). During resistance training, flexibility training should be increased accordingly. As anticipated, flexibility, explosive strength, floor reaction time and anthropometric characteristics account, in fact, for 41% of the success in rhythmic gymnastics (Di Cagno et al., 2008). In this study, lower limb flexibility did not change after either unspecific and specific training, except for internal rotation, *i.e.* an outward rotation of the legs at the hips level, which however is an important technical requirement for rhythmic gymnastics because it is necessary to perform all technical elements correctly and to reach a good balance.

Recent studies on pre-adolescent strength training have highlighted the physiological and psychological benefits of properly designed and well supervised resistance training (American Academic of Pediatrics, 2008; Harries, et al., 2012). This study has provided further evidence that high repetition of low intensity resistance exercises is advisable for young rhythmic gymnasts to improve power and stiffness and that specific training appears to be preferable as it increases reactive strength. Coaches may use this knowledge when designing appropriate training loads for this population of young athletes.

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The authors declare that they have no conflicts of interest with respect to their authorship or the publication of this article. No financial support was given for this study.

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