IMPLEMENTING A PROGRESSIVE RESISTANCE TRAINING PROGRAM IN YOUTH JUNIOR OLYMPIC WOMEN'S GYMNASTICS

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Abstract

Competitive gymnasts in the Women's Junior Olympic (JO) program are highly conditioned, typically training 8-20 hours per week. Training often consists of high-repetition body-weight activities with little variability. This method of training lacks progressive resistance exercise (PRE) training, a cornerstone for muscular adaptation. To investigate the benefits of 10 weeks of PRE training, 1 day/week, on muscular strength and power in women's JO child and adolescent gymnasts. 50 females aged 7-17 years (mean 10.2±2.7 years), competing on JO levels 3-10 participated. Gymnasts in JO Levels 3 and 4 were divided into either the Control Group or the PRE group. The Control Group continued the standard non-PRE conditioning. The PRE Group underwent the prescribed PRE training. Level 5-10 gymnasts also underwent PRE training and were separately analyzed in a quasi-experimental repeated measures design. 15 exercises were completed. Tests for lower- and upper-body power included vertical leap and a modified Wingate arm-ergometer anaerobic test (Arm-WAnT). Compared to the Control Group, the PRE Group had a greater improvement in vertical power (p=0.003), and Arm-WAnT peak power and mean power (p=0.044 and 0.023), but no difference in Arm-WAnT fatigue index. Gymnasts in Levels 5 to 10 similarly improved vertical power (2224±756W to 2473±688W, p<0.001), Arm-WAnT peak power (80.9±30.1W to 93.2±40.6W, p<0.001), and mean power (62.8±23.2 to 70.1±27.3, p<0.001), with no change in Arm-WAnT fatigue index. 10 weeks of PRE will improve upper- and lower-body power in child and adolescent female JO gymnasts.

Keywords: *Plyometric, Athletic performance, Resistance training, Junior Olympic, Circuit training.*

INTRODUCTION

Competitive gymnasts in the USAG Women's Junior Olympic (JO) Artistic Gymnastics program are well-trained and highly conditioned. In the United States, JO gymnasts typically train 8-20 hours per week (USA Gymnastics, 2006), with greater training volumes at higher JO levels. The ever-increasing difficulty level in women's gymnastics continues to emphasize the need for improved strength. In many gyms training consists primarily of repetitions of strength-oriented gymnastics skills and high-repetition conditioning utilizing only body-weight resistance with little variability in the exercises performed. The nature of this low-resistance, high-repetition conditioning has limited the continued improvement in the gymnasts' strength (Sands et al., 2000). This method of training lacks progressive resistance exercise (PRE) training, a cornerstone to stimulating further adaptation for specific training goals (American College of Sports Medicine (ACSM), 2009). While current training exercises are usually specific to gymnastics performance, they lack progressive overload and variation.

Despite anticipated benefits of PRE, many coaches have been hesitant to implement resistance training programs because of persistent and disproven beliefs that resistance training is dangerous for children (Faigenbaum et al., 2009; McCambridge & Stricker, 2008), may result in undesirable bulking (Sands et al., 2000) and/or loss of flexibility (O'Sullivan et al., 2012).

The goal of this study was to investigate the effects of ten weeks of progressive resistance training on upper- and lower-body muscular power in JO female gymnasts. It was our intent to utilize training methods that were available to most gyms that may not have access to traditional weight training equipment, and coaches who are generally reluctant to sacrifice gymnastics training time. This study, therefore, utilized minimal training equipment and only one day of PRE per week. We hypothesized that once weekly PRE would significantly improve upper- and lower-body muscular power after ten weeks of training compared to standard training. We further hypothesized that once weekly PRE would significantly improve the upper-body anaerobic fatigue index.

METHODS

Gymnasts were tested before and after ten weeks of training. Gymnasts in the JO Levels 3 and 4 were divided into either the Control Group or the PRE Group. The Control Group continued the standard body-weight conditioning normally prescribed by the coaches; i.e., non-PRE conditioning. They were compared to the PRE Group that underwent PRE training. The Control and PRE Groups were matched for training duration and frequency, as well as being of equivalent age and gymnastics experience (Table 1). The Control and PRE Groups were divided by scheduled practice time which differed by the days of the week on which they practiced, but their training was otherwise equivalent. Researchers coordinated with coaches and attended practices to ensure that athletes and coaches did not deviate from their assigned training groups. Gymnasts in JO Levels 5-10 completed the PRE training, acting as their own controls. These gymnasts were analyzed separately using a quasi-experimental repeated-measures design.

50 female gymnasts, aged 6-17 years, completed 10 weeks of training. Gymnasts had previously qualified for JO levels 3-10 competitive teams following USAG guidelines. Gymnasts who had an injury or physical limitation that made them unable to perform strenuous physical activity and forced them to refrain from their typical gymnastics practice were excluded. All gymnasts were part of the same team. None of the gymnasts had a history of progressive resistance exercise training, however, all gymnasts had a history of strenuous gymnastics conditioning which consisted of repetitive low-resistance, high-repetition body-weight exercises. Prior to testing, child assent and parental consent were obtained as approved by the Institutional Review Board in full accordance with the ethical standards of the Helsinki Declaration.

All gymnasts in the PRE Group trained together, completing 15 sport-specific exercises (Table 2) performed once per week during a 45-minute circuit training session. During training, gymnasts recorded the resistance, repetitions, and their perceived effort for each exercise. This information was used to track and prescribe progressive increases in the gymnasts' training loads. The prescribed exercises trained all major muscle groups using both isotonic and plyometric exercises (Figure 1). All exercises were prescribed for 10-12 repetitions or until failure, unless otherwise indicated (Table 2). Resistance included free weights, resistance bands, and medicine balls. To ensure that athletes exercised safely and utilized proper form, all exercises were supervised by researchers and coaches at each station in the circuit.

Figure 1. Example of body-weight plyometric exercises. Plyometric Jumps Challenge. ~61in (154cm) shown.

Power testing

Upper- and lower-body power were assessed before and after 10 weeks of training. Lower-body power was assessed using a counter-movement vertical leap. Upper-body power was assessed using a Wingate-style anaerobic arm-ergometer test. Upper body fatigue index was also assessed using the arm-ergometer test. Prior to testing, all gymnasts completed their normal team warm-up routine.

Vertical Leap

Vertical leap is a valid (Leard et al., 2007) and reliable (Glencross, 1966) field test of vertical power and lower body anaerobic power (Tharp et al., 2013). Using a Vertec (JumpUSA), gymnasts jumped off two feet from a standstill using a counter-movement jump, reaching up with their self-identified dominant hand. Standing reach was measured with the gymnasts standing flat-footed and reaching as high as they were able with their dominant hand. Prior to jumping, body weight was measured, the gymnasts were given a brief tutorial, and they were allowed a submaximal practice to ensure proper form. The measured difference between the standing reach and the leaping reach indicated the vertical leap. The best of three attempts was used to calculate vertical power. Vertical power was calculated using a model specific to children and adolescents (Gomez-Bruton et al., 2017):

$$Power\ (W) = 54.2 * VJH(cm) + 34.4 * body\ mass(kg) - 1520.4$$

Anaerobic Arm-Ergometer Test

Gymnasts performed a 30-second Wingate-style anaerobic test on a mechanically-braked arm ergometer (Monarch 881e). Similar to the traditional cycle-ergometer Wingate anaerobic test (Dotan & Bar-Or, 1983), gymnasts completed a five-minute warm-up against minimal resistance, interspersed with three or four five-second sprints against progressively increasing resistance. After the warm-up, there was a one-minute rest. As the test began, gymnasts pedaled as fast as possible, initially against inertial resistance only. The prescribed resistance (3.2% to 5% BW) was added over three to five seconds, after which the 30-second timer was started. Revolutions per five-second interval were used to calculate peak power, mean power, and fatigue index as previously described (Dotan & Bar-Or, 1983).

Statistical analyses were conducted using SYSTAT 13. Data were tested for assumptions of normality and homogeneity of variance. Gymnasts were included in the final analysis if they completed at least 70% of the training sessions. To analyze the difference between the PRE Group and Control Group, change values with training were calculated and compared via independent t-test. The changes in 5-10 PRE Group from before to after training were assessed via paired t-test. α=0.05 for all tests. Values are presented as mean±SD.

Table 1
Subject Characteristics.

	Control (n=19)	PRE (n=9)	Level 5-10 PRE (n=22)
Age (yrs)	8±1.5 (6-11)	9±1.3 (7-12)	12±6.2 (8-17)
Gymnastics Experience (yrs)	2-4	3-4	3-13
Height (cm)	130±8	135±9	147±11
Weight (kg)	28±6	31±6	41±11

Age range is presented in parentheses. No significant difference between Control and PRE Groups (p>0.05). Gymnastics experience represents years of training with formal coaching. Gymnasts completed at least 70% of the training sessions. Values are mean±SD.

Table 2
PRE Training Exercises.

Exercise	Brief Description	Resistance
Shoulder Press	Stand on the middle of the resistance band, elbows to the side, holding the ends of the band at the shoulders, press both arms overhead to full extension	Resistance bands – adjusted length and band resistance
Single-leg Calf Raises	Stand on the edge of a platform, ankle extension through full range of motion	Handheld weights
Triceps Pops	Push-up position, elbows in, feet remain on the floor. In one movement push off the floor forcefully, quickly move hands up to stacked panel mats	Increased goal height of stacked panel mats
Back Extensions	Torso hanging from an elevated surface perpendicular to the floor, legs parallel to the floor, weight held to the chest, raise torso through full lower back extension	Handheld weights
Plyometric Jumps Low	On sprung floor, plyometric jumps forwards to series of approx. 60cm platforms, approx. 1.5 m apart	Increased speed of completion

Plyometric Jumps Challenge	On sprung floor, single plyometric jump from 24 in platform to highest achievable height	Increased goal height – stacked panel mats, table trainer
Deadlifts	Stand on the middle of the resistance band with both feet, pull on ends of the band through standard deadlift range of motion	Resistance bands – adjusted length and band resistance
2-Arm Ball Throw	Feet staggered, medicine ball held at the forehead, ball is thrown forward as far as possible, emphasizing triceps	Medicine Balls
1-leg box jumps	Single-leg jumps up (forward) and down (backward) from a stack of mats, alternating legs for each jump	Increased stack of panel mats
Pistol Squats	Single-leg squats with supporting leg to approx. 90^0, opposite leg held straight anteriorly	Handheld weights
Shoulder 3-way	While standing straight arms are abducted from the side through approx. 90^0, anterior, lateral, and posterior	Handheld weights
Plyometric Abs	Lie supine with a partner standing on either side of the head. Partner's ankles are held for support. Flexion at the hip and lower back to raise straight legs forcefully towards the standing partner. Standing partner forcefully throws straight legs back down, legs are stopped just before hitting the floor, then flexion is forcefully repeated	Partner increases force of leg throw
Star Excursion Balance	Star excursion balance exercise using an unstable surface reaching the unsupported leg anteriorly, posteromedial, and posterolateral as far as possible (Kinzey & Armstrong, 1998)	Progressively less stable surface – carpet, foam balance pad, Dynadisc
Tricep dips	Straight legs are supported at the ankle by partner, held parallel to the ground. Hands on the balance beam, bend at the elbows to approx. 90^0 to dip the torso below the top of the beam, then press upwards, focusing on elbow extension	Medicine balls held on lap
Hanging Abs	Hang from bar, quickly raise straight legs, touching toes to the bar, slowly return to full extension and repeat	Increased repetitions to failure

Exercises were performed with a partner under the supervision of researcher or coach. Exercises were performed in the same order through a circuit. The starting point of the circuit was random for each gymnast. All exercises were prescribed for 10-12 repetitions or until failure, unless otherwise indicated.

RESULTS

50 gymnasts completed at least 70% of the training sessions and were included in the final analysis, including 19 in the Control Group, nine in the PRE Group, and 22 in the Levels 5-10 PRE Group (Table 1).

Vertical Leap

The PRE Group had a significantly greater improvement in vertical power than the Control Group, increasing by 235.2±50.7 Watts and 80.1±205.4 Watts respectively ($p=0.018$) (Figure 2). Similarly, the 5-10 PRE Group significantly improved their vertical power compared to the baseline by 225.9±206.3 Watts ($p<0.001$) (Figure 2).

Anaerobic Arm-Ergometer Test

PRE training resulted in a significantly greater peak power on the anaerobic arm-ergometer test. The PRE Group increased peak power by 12.3±14.3 Watts compared to an increase of 3.2±9.1 Watts in the Control Group ($p=0.027$). Similarly, the 5-10 PRE Group increased peak power by 16.0±22.9 Watts compared to the baseline ($p=0.006$) (Figure 2). Mean power on the anaerobic arm-ergometer test also significantly increased with PRE training. The PRE Group increased mean power by 6.8±5.0 Watts compared to an increase of 2.7±3.1 Watts in the Control Group ($p=0.007$). The 5-10 PRE Group significantly increased mean power by 10.3±13.8 Watts compared to the baseline ($p=0.001$) (Figure 2). There was no significant difference in fatigue index between the PRE and Control Groups ($p=0.245$) or between timepoints for the 5-10 PRE Group ($p=0.443$). Overall, fatigue index before training was 39.1±13.3% compared to 40.2±10.5% after training.

DISCUSSION

It was the goal of this study to implement and assess a pragmatic progressive resistance exercise training program for child and adolescent female JO gymnasts. Previous published research in gymnasts has focused on older college and elite level gymnasts with access to the traditional weight training equipment and more available training time to undergo more traditional PRE training (Brooks, 2003; James, 1987; Sands et al., 2000). We demonstrated an effective PRE training program that could be completed in only 45 minutes, one day per week, using minimal training equipment. We observed significant improvement in upper- and lower-body muscular power. These results were consistent when compared to the Control Group in the lower JO levels 3 and 4, as well as within the upper JO levels 5-10.

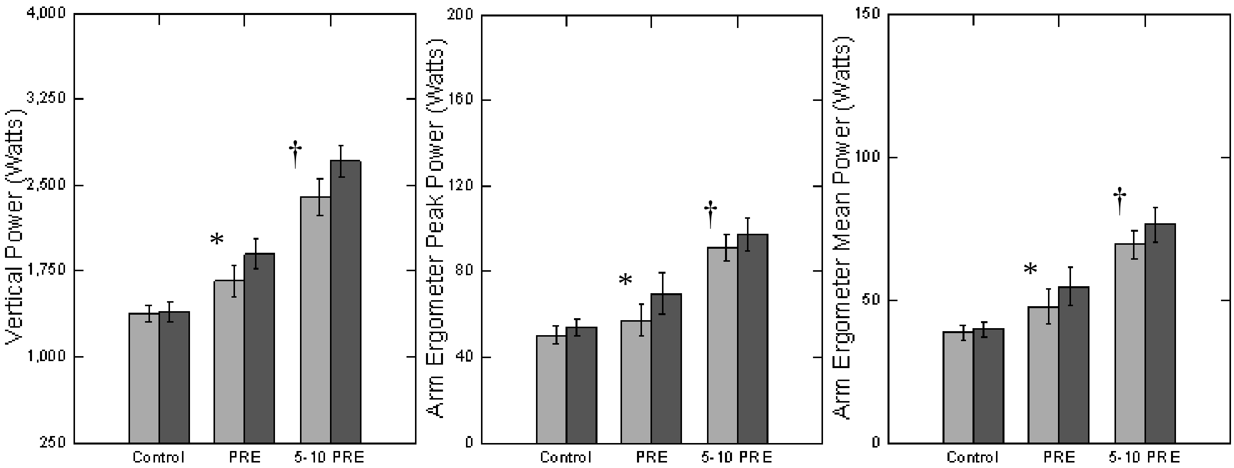

Figure 2. Changes in upper- and lower-body power with training. Bars represent values before and after training for each group. * indicates significantly greater change with training compared to the Control Group (p<0.050). † indicates significant change with training compared to the baseline (p<0.050). Not shown, there was no significant change in fatigue index with training.

The improvement in muscular power we observed in these female child and adolescent gymnasts is consistent with previous studies examining strength training in similar age groups (Akın, 2013; Dahab & McCambridge, 2009; Faigenbaum et al., 2009; McCambridge & Stricker, 2008; Myers et al., 2017). The current study was not designed to assess mechanisms of improved muscular strength or power. Previous literature indicates that in pre-pubescent children, improvements in strength are more strongly influenced by neuromuscular improvements than hypertrophy, including improved motor unit recruitment and firing rate, and motor coordination (Falk & Eliakim, 2003; Legerlotz et al., 2016; Ozmun et al., 1994). Muscle hypertrophy seen in children (Fukunaga et al., 1992) is expected to be small relative to the change in strength, and a lesser contributor to strength improvement compared to adults (Hass et al., 2001). In adolescents, we may expect greater hypertrophy compared to children; however, evidence indicates the hypertrophic response to resistance training remains less than in adults (Legerlotz et al., 2016). Coaches are often reluctant to incorporate strength training for fear of bulking of the gymnasts (Sands et al., 2000). Previous research in upper level gymnasts has actually shown that typical gymnastics strength training that consists of high repetition body weight exercises is more likely to contribute to bulking with less benefit to strength (Sands et al., 2000).Twice weekly PRE is generally accepted as the minimum to elicit significant strength gains in adults (ACSM, 2014; Dahab & McCambridge, 2009) and children (Faigenbaum et al., 2009) . While our program was only implemented once weekly, the gymnasts maintained their normal body-weight, non-progressive conditioning during regular practices on the other 2-4 days per week, depending on their JO level. These results demonstrated that the addition of once-weekly bout of PRE training provided a sufficient overload stimulus to result in significant improvement in upper- and lower-body muscular power.

CONCLUSIONS

As a sport, gymnastics requires substantial practice time and financial investment. Therefore, this training program was designed to keep time and costs at a minimum while still providing an effective training stimulus. We effectively demonstrated that despite the high level of conditioning these athletes undergo, the addition of once-weekly PRE training can significantly improve muscular power, and thus increase their potential to improve gymnastics performance.

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