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Original research article

THE EFFECTS OF A PLYOMETRIC AND STRENGTH TRAINING PROGRAM ON THE FITNESS PERFORMANCE IN YOUNG BASKETBALL PLAYERS *

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Abstract. *The aim of this study was to evaluate and compare the effects of two short-term off-season conditioning training programs on fitness performance in young basketball players. Twenty-one young basketball players, aged 12-13 years, volunteered to participate in this study. The participants were randomly assigned to a strength training group (ST, n = 10) or a combined plyometric and strength training group (CT, n = 11). The ST group performed free full court basketball play followed by strength training, whereas the CT group performed plyometric exercises followed by the same strength training program. Young basketball players were assessed before and after a six-week training period on the vertical jump, long jump, medicine ball toss, 20 m sprint, 4 x 15 m standing start running and stand and reach flexibility. The CT group made significantly ($p < 0.05$) greater improvements than the ST group in the vertical jump (3.2 cm vs. 0.6 cm), long jump (10.3 cm vs. 2.2 cm), 20 m sprint (-0.2 sec vs. 0.0 sec), 4 x 15 m standing start running (-0.41 sec vs. -0.05 sec) and the medicine ball toss (40.7 cm vs. 18.2 cm) following the training. The results of this study demonstrate that a short-term plyometric and strength training program significantly increases motor performance skills in young basketball players.*

Key words: *youth basketball, off-season, programmed training, motor performance skills.*

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INTRODUCTION

Plyometric and strength training are referred to as improving the most powerful motor performance skills in young basketball players (Fulton, 1992; Matavulj, Kukolj, Ugarković, Tihanyi & Jarić., 2001; Radcliffe & Farentinos, 1999) and they are a significant component of most conditioning program designs. Plyometric training (also called stretch-shortening cycle exercises) is often used during the off-season basketball training program (Adkins, Bain, Dreyer & Starkey, 2007; McKeag, 2003) as an effective method for improving motor performance (Andrejić, 2009; Fulton, 1992; Matavulj et al., 2001; Radcliffe & Farentinos, 1999). Strength training is also a very important part of basketball off-season programs (Fulton, 1992, Price, 2006) with a background of related benefits that improve motor performance (Fleck & Kraemer, 2004; Micheli, & Purcell, 2007) and reduce injury rate (McKeag, 2003).

Plyometric drills are often combined with strength training, with the presumption that motor performance may be enhanced to a significantly greater extent than each program performed alone (Adams, O'Shea, O'Shea & Climstein, 1992; Faigenbaum et al., 2007; Fatouros et al., 2000; Myer, Ford, Palumbo & Hewitt, 2005; Santos & Janeira, 2008). Plyometric training may "prime" the neuromuscular system for the demands of strength training by activating additional neural pathways and enhancing the neuromuscular system to a greater degree of readiness (Linnamo et al., 2000). The use of both plyometric and strength trainings in the same workout is also an adequate strategy of training process organization, which has highly positive effects on practice and training time management. Because of the growing popularity of youth strength and conditioning programs, along with the potential health benefits associated with this methods (Faigenbaum & Westcott, 2009), it is important to find the most efficient method for enhancing fitness performance in young athletes.

The hypothesis of this study was that the combinatory effects of plyometric and strength training would result in significantly greater improvements in motor performance skills.

THE METHOD

Two groups (a strength training group and combined plyometric and strength training group) were selected for this purpose. The combined plyometric and strength training group (CT group) performed plyometric exercises, while the strength training group (ST group) performed free full court basketball. Following that, all of the participants took part in the same strength training program. Changes in all the variables were measured before and after the six-week training program.

The participants

The participants were twenty-one healthy boys who are members of the *Panthers* basketball club. They were randomly assigned to either a strength training group (n = 11: age, 12.5 ± 0.5 years old; weight, 62.0 ± 7.1kg; height, 173.1 ± 5.3 cm; BMI 20.7 ± 2.1; and basketball training experience 1.5 ± 0.5years) or a combined strength training and plyometric training group (n = 10: age, 12.6 ± 0.5 years old; weight, 58 ± 5.8 kg; height, 171.6 ± 7.8 cm; BMI 19.8 ± 2.3; and basketball training experience 1.6 ± 0.5years).

None of the participants had had any training experience with a strength and plyometric training program before this study. The participants and their parents were informed about the nature of this project and consent was obtained from them before the study began. The coaches were carefully informed about the experimental procedures and the possible risk and benefits of the project. All of the study procedures took place at Branko Radičević school athletic facility.

Procedures

Six tests were selected for the evaluation of fitness performance. These tests are often used to assess performance in athletes (Andrejić, 2009; Jovanović, 1994; Safrit, 1995). The test procedures for the vertical jump, long jump, 4 x 15 m standing start running and stand and reach flexibility test can be found in Andrejić, Tošić & Knežević, 2012, the seated medicine ball toss in Faigenbaum at al., 2007, and the 20 m sprint, in Jovanović, 1994. The training program used in this study was designed by the author of this research and it is based on the findings from previous publications (Faigenbaum & Westcott, 2000; Radcliffe & Farentinos, 1999). Both training groups trained twice per week on nonconsecutive days for six weeks. Experienced physical education teachers and certified basketball coaches discussed and demonstrated proper exercise technique throughout the study period. The training was done under close supervision with frequent adjustments in training intensity to maintain the desired training stimulus. The training duration for both groups was 90 minutes. The participants in both training groups took part in a 15 minute warm-up period which consisted of a moderate-intensity dynamic exercises session. Recent observations suggest that this may be the most effective warm-up protocol for enhancing power performance in boys (Andrejić, 2012). After the warm-up period the CT group performed plyometric exercises, while the ST group performed free full court basketball (~25 min). Following that, all of the participants took part in the same strength training program (~45 min). Each training session ended with ~5 minutes of cool-down activities (static stretching). No form of any other strength program outside the research setting was allowed. Young basketball players participated in their schools physical education program during the study.

The warm-up protocol: the warm-up protocol consisted of 5 minutes of low to moderate intensity jogging followed by moderate to high intensity dynamic exercises. The dynamic warm-up exercises that were used included: the high knee skip, high knee run, butt kick, carioca, lateral shuffle, walking lunge, side to side kick and front-and-back kick. Detailed descriptions of these stretches can be found in National Basketball Conditioning Coaches Association - NBCCA (2007).

Full-court basketball play: Full court basketball play was carefully considered during off-season because this type of training adds to the chronic repetitive stress placed on the musculoskeletal system (Faigenbaum et al., 2005).

Plyometric training: The plyometric training program consisted of three levels. The participants performed 10 plyometric exercises during weeks one and two (1 set of 6 repetitions) and 12 plyometric exercises during weeks three through six (weeks three and four; 1 set of 5 repetitions, and weeks five and six; 1 set of 4 repetitions). Exercises followed protocols previously described elsewhere (Radcliffe & Farentinos, 1999).

Table 1. Summary of the plyometric training program.

Weeks 1 and 2 1 set / 6 repetitions	Weeks 3 and 4 1 set /5 repetitions	Weeks 5 and 6 1 set / 4 repetitions
Fast skipping	Double-leg butt kick	Single-leg stride jump
Pogo	Knee-tuck jump	Stride jump crossover
Rocket jump	Split jump	Quick leap
MB over and under	Scissors jump	Depth jump
MB full twist	Alternate leg bound	Box jump (MR)
MB chest pass	Twist toss	MB scoop toss (MR)
Double-leg speed hop	MB ball scoop throw	Mult. hops to overhead throw
Double-leg hop progression	Sit-up throw	Mult. hops to underhand toss
Side hop	Single-leg butt kick	Lateral bound
Side hop sprint	Single-leg hop progression	Box skip
	Single-leg diagonal hop	Box bound
	Single-leg lateral hop	Depth leap

MB = medicine ball; MR = multiple response

Strength training: Following the free full court basketball or plyometric training, all of the participants took part in the same progressive strength training program. Strength training programs for youth, which include rubber cord exercises and body weight exercises, have been reported as effective in previous studies (Faigenbaum & Westcott, 2000; Faigenbaum & Westcott, 2009). Exercises followed protocols previously described (Faigenbaum & Westcott, 2000). Different sizes and types of rubber cords were used, so young athletes could start at safe levels and progress as needed. On the trunk curl and back extension body weight exercises, the participants used the medicine ball to provide a general conditioning effect.

Table 2. Summary of the strength training program.

Rubber cord exercises (1 set / 8-12 repetitions*)	Rubber cord standing chest press Rubber cord triceps extension Rubber cord seated row Rubber cord biceps curl Rubber cord seated shoulder press Rubber cord lateral raise Rubber cord squat
Body weight exercises (1 set / 12 to 25 repetitions)	Trunk curl (MB) Back extension (MB) Hanging-knee raise Kneeling-trunk extension Heel raise.

MB = medicine ball; *The last repetition of the second strength training set on each exercise represented momentary muscular fatigue.

Statistical Analyses

A descriptive statistics (mean ± SD) was calculated for all of the variables. The independent sample t-test was used to detect differences between the study groups for all the baseline variables. An analysis of variance (ANOVA) was used to determine whether differences existed between groups in the changes in each variable from the baseline to the posttest. When the significant main effects and interactions were observed, the post-hoc paired t-test with a Bonferroni adjustment were utilized for indentifying the specific differences. All of the data were conducted using SPSS, version 11.0 (SPSS, Inc. Chicago, IL, USA). The significance level was set at $p < 0.05$.

RESULTS

Baseline and post-training motor performance skills scores in both groups are presented in Table 3. All of the participants completed the study with 100% compliance, and there were no injuries resulting from either training program. After the training program, the CT group made significant improvements on all of the tests, whereas the ST group made significant improvements on the medicine ball toss and stand and reach flexibility test only. Neither group differed significantly at the baseline in assessed fitness performance level, and the CT group made a significantly greater improvement in the vertical jump, long jump, 20 m sprint, 4 x 15 m standing start running, and medicine ball toss, than the ST group.

Table 3. Baseline and post-training motor performance skills scores

Variable	Group	Baseline	Post-training	Gains	
				Absolute	%
Vertical jump (cm)	ST	40.2 ± 6.2	40.8 ± 5.6	0.6	1.5
	CT	41.2 ± 7.6	44.4 ± 8.4*†	3.2	7.8
Long jump (cm)	ST	189.6 ± 10.0	191.8 ± 12.3	2.2	1.2
	CT	193.9 ± 19.6	204.2 ± 22.7* †	10.3	5.3
20 m sprint (sec)	ST	4.16 ± 0.3	4.16 ± 0.2	0.0	0.0
	CT	3.76 ± 0.3	3.56 ± 0.3* †	-0.2	-5.3
4 x 15m standing start running (sec)	ST	15.37 ± 0.6	15.32 ± 0.5	-0.05	-0.3
	CT	15.42 ± 0.5	15.01 ± 0.5*†	-0.41	-2.7
Medicine Ball Toss (cm)	ST	401.0 ± 60.7	419.2 ± 61.8 *	18.2	4.5
	CT	399.5 ± 75	440.2 ± 66 * †	40.7	10.2
Stand and Reach (cm)	ST	-1.7 ± 5.4	-4.6 ± 5.1*	2.9	170.5
	CT	-2.1 ± 4.1	-5.4 ± 3.9*	3.3	157.1

ST, strength training group; CT, combined plyometric training and strength training group;
* Significantly greater improvement compared to the baseline ($p < 0.05$);
† Significantly greater improvement than the ST group ($p < 0.05$).

DISCUSSION

As hypothesized, a combined plyometric and strength training program resulted in significantly greater improvements in motor performance skills. Young basketball players in the CT group made significantly greater improvements in upper and lower body power which are usually seen as essential for basketball performance (Fulton, 1992). The CT group made significantly greater improvements in the vertical jump height (7.8% vs. 1.5%) than the ST group. These results are in agreement with previous findings demonstrated by Adams et al. (1992). They found that participants who used a combined plyometrics and squat training program had more significant increases in vertical jump height than participants who trained with squats or plyometric alone. Additionally, Fatouros et al. (2000) found that the combined training group (plyometric and strength training) showed signs of improvements in their vertical jump performance and leg strength that were significantly greater than the improvements in the other two training groups (plyometric training and weight training). The CT group made significantly greater improvements in the distance of their long jump (5.3% vs. 1.2%) compared to the ST group. Faigenbaum et al. (2005) obtained similar results. They compared the effects of a six week training period of combined plyometric and strength training versus strength training alone on the fitness performance of boys (12-15 yr), and found that the combined plyometric and strength group made significantly greater improvement in the long jump (6.0 vs. 1.1%) than the strength training group. The CT group made significantly greater improvement than the ST group in the distance of the medicine ball tosses (10.2% vs. 4.5%) after the training program. This difference is likely due to the upper body plyometric exercises with medicine balls that were incorporated into the CT group program. Both groups performed the same upper body strength training protocol, but the effects of plyometric training added to the strength training protocol, which likely resulted in better synchronization of body segments, increased coordination levels, and a greater muscular strength/force. These results are consistent with the findings reported by Vossen, Burke & Vossen (2000) and Faigenbaum et al. (2007), who noted that the combined practice of upper body plyometrics and strength may improve upper body power performance. The results from the current study suggest that both training programs may increase gains in flexibility assessed with the stand and reach test by about 3 cm. This is in agreement with the report of Faigenbaum et al. (2007) who compared the effects of short-term plyometric and strength training on flexibility in boys aged 12 to 15. Because lower back and hamstring flexibility improved in both groups, it appears that strength training will not result in a loss of flexibility in young basketball players. The current study indicated that combined plyometric and strength training significantly improved performance in the 20 m sprint test compared to strength training alone (5.3% vs. 0%, respectively). This data concur with the findings by Kotzamanidis (2006) who noted that running velocity improved for the distance of 10 to 20 m and 20 to 30 m in prepubescent boys following 10 weeks of plyometric training. Diallo, Dore, Duche & Van Praagh (2001) reported an increased performance in the 20 m sprint after a 10-week plyometric training program involving boys aged 12-13 years.

Basketball players from the CT group also made significantly greater improvements in the 4 x 15 standing start running test (2.7% vs. 0.3%), compared to the ST group. It may be hypothesized that the combined plyometric and strength training will most likely enhance performance in activities which involve acceleration and deceleration and change of direction. The performance of the 4 x 15 standing start running test consisted of frequent and rapid starts and stops, as well as a change in direction, and is obviously determined on the level of the explosive muscle power and flexibility (Andrejić & Berić, 2008). As previously noted, the combined plyometric and strength training program enhanced explosive muscle power and flexibility, which was related with success in the 4 x 15 agility test. The ST group made significant improvements on the medicine ball toss and stand and reach flexibility test only. Gains in strength and power in youth basketball players have already been noted after incorporating some type of strength training into basketball training sessions (Vamvakoudis et al., 2007). This finding is in agreement with the previous studies which suggested that regular participation in a well-designed strength program will result in some degree of improvement in motor performance (Micheli & Purcell, 2007).

Correctly designed and competently supervised, both training programs carry no extra overload on young athletes' skeletal muscles as proved by the absence of injury during the training program. Also, none of the participants missed training practice or basketball games due to injury in the following year-round cycle. We assume that both off-season conditioning programs helped to the young basketball players to have an injury-free season. As described previously (Koutures & Gregory, 2010; Myer et al., 2005), comprehensive conditioning programs that included strength and plyometric training have proven to be an effective strategy for reducing sports-related injuries in young athletes.

Basketball players were 12.5 ± 5 years old, so some of the boys may have been preadolescent, and some of them may have been adolescent. Another drawback is the different amounts of physical conditioning between groups. The training duration for both groups was 90 minutes, but the CT group performed plyometric sessions prior to strength training sessions, and the ST group performed full court basketball play prior to the same strength training sessions, so the CT group performed more physical conditioning than the ST group.

CONCLUSION

It is important to discover the most efficient method for enhancing motor performance in young basketball players. The findings of this study highlight the potential value of combined plyometric and strength training in an off-season conditioning program aimed at maximizing motor performance in young basketball players. The findings basically suggest that participation in an off-season combined plyometric and strength program of high intensity, even of short-term duration, contributes to the improvement in the motor performances of young basketball players. A combined plyometric and strength training program is a time-effective and safe training modality that confers significant improvements in the motor performance of young basketball players. On the basis of this and previous findings, we can suppose that the effects of plyometric and strength training may be synergetic in young basketball players, with their combined effects being greater than the independent effect of strength training alone. The present study also confirmed that it is possible to achieve significant statistical progress in the motor performance provided by a short-term training program (two sessions per week for six weeks), while using inexpensive and available equipment. Combined plyometric and strength training may be a useful working tool for coaches, innovative in this strength-power training domain, equally contributing to a more time-efficient training.

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EFEKTI PLIOMETRIJSKIH TRENINGA I VEŽBI SNAGE NA FITNES PERFORMANSE KOŠARKAŠA MLAĐIH KATEGORIJA

Ognjen Andrejić

Aktuelno istraživanje je imalo za cilj da proceni i uporedi efekte dva kratkoročna kondiciona programa za košarkaše mlađih kategorija, koja su sprovedena u prelaznom periodu. Istraživanje je obuhvatilo dvadeset i jednog košarkaša starosti 12-13 godina. Ispitanici su nasumično podeljeni u dve grupe: grupu koja je koristila vežbe snage (ST, n = 10) i grupu koja je kombinovala pliometrijski trening sa vežbama snage (CT, n = 11). ST grupa je vežbe snage izvodila posle "igre na dva koša" dok je CT grupa vežbe snage izvodila posle pliometrijskih vežbi. Fitnes performanse mladih košarkaša su pre i posle šestonedeljnog trenažnog perioda procenjivane skokom u dalj, skokom u vis, bacanjem medicinke, sprintom na 20m, trčanjem 4 x 15m i pretklonom u stojećem stavu. CT grupa je nakon trenažnog perioda pokazala statistički značajan napredak u skoku u vis (3.2 cm vs. 0.6 cm), skoku u dalj (10.3 cm vs. 2.2 cm), trčanju na 20 m (-0.2 sec vs. 0.0 sec), trčanju 4 x 15 m (-0.41 sec vs. -0.05 sec) i bacanju medicinke (40.7 cm vs. 18.2 cm). Rezultati ovog istraživanja pokazali su da je pliometrijski trening kombinovan sa treningom snage u kratkom vremenskom periodu značajno povećao motoričke sposobnosti mladih košarkaša.

Ključne reči: *Košarkaši mlađih kategorija, prelazni period, programirani trening, motoričke sposobnosti.*