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The Effect of Six Weeks of Squat, Plyometric and Squat-Plyometric Training on Power Production

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ABSTRACT

Adams, K., O'Shea, J.P., O'Shea, K.L. and M. Climstein. The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *J. Appl. Sport Sci. Res.* 6(1):36-41. 1992. — *Explosive leg power is a key ingredient to maximizing vertical jump performance. In training, the athlete must use the most effective program to optimize leg power development. The purpose of this study was to compare the effectiveness of three training programs — squat (S), plyometric (P) and squat-plyometric (SP) — in increasing hip and thigh power production as measured by vertical jump. Forty-eight subjects were divided equally into four groups: S, P, SP or control (C). The subjects trained two days a week for a total of seven weeks, which consisted of a one-week technique learning period followed by a six-week periodized S, P or SP training program. Hip and thigh power were tested before and after training using the vertical jump test, and the alpha level was set at 0.05. Statistical analysis of the data revealed a significant increase in hip and thigh power production, as measured by vertical jump, within all three treatment groups. The SP group achieved a statistically greater improvement ($p < 0.0001$) than the S or P groups alone. Examination of the mean scores shows that the S group increased 3.30 centimeters in vertical jump, the P group increased 3.81 centimeters and the SP group increased 10.67 centimeters. The results indicate that both S and P training are necessary for improving hip and thigh power production as measured by vertical jumping ability.*

KEY WORDS: plyometrics, squats, speed-strength, power, periodization

INTRODUCTION

Success in many sports depends heavily upon the athlete's explosive leg power. In jumping, throwing, track and field events and other activities, the athlete must be able to use strength as quickly and forcefully as possible. This display comes in the form of speed-strength or power (23). Power represents the amount of work a muscle can produce per unit of time. An increase in power gives the athlete the possibility of improved performance in sports in which the improvement of the speed-strength relationship is sought.

Combined parallel squat and plyometric training and its effects on vertical jump ability has not been investigated extensively or in depth. A limited number of studies on this topic have been published in research journals (2, 5, 9, 19, 20). The primary limitations of these studies, even though they resulted in significant improvement, can be found in their experimental design. None used a progressive athletic weight-training program as followed in this study. The studies cited simply referred to conventional weight training. In one study, the subjects were trained using an isokinetic leg press machine in place of the full squat (2). Certainly, this cannot be considered the typical program in terms of training quality and intensity as followed by athletes involved in explosive power sports or events. If so-called conventional weight training can result in greater vertical jump ability, what would be the response to an intense six-week microcycle of combined parallel squats and plyometrics?

This study was limited to a six-week, twice-per-week, microcycle for a number of reasons. From a physiological and psychological standpoint, four to six weeks of high-intensity power training is the optimal length of time that the

Table 1. Squat Program

Warm-up

Back and leg stretch	5 min
Squat 1 x 10	60 kg
10-15 kg jumps	1-5 reps up to workout weight

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Tuesday	4 x 8 70%	4 x 6 80%	3 x 5 85%	3 x 3 90%	2 x 3 95%	2 x 2 100%
Friday	2 x 8 50%	2 x 8 60%	2 x 8 70%	1 x 8 70%	1 x 8 70%	Rest

Sets x reps at percentage of 1 RM

central nervous system can be stressed without excessive strain or fatigue (3, 16). It is the belief of some sports physiologists that neuromuscular adaptations contributing to explosive power may occur early (within the first two to four weeks) in a power cycle (12, 15, 18). Squats and plyometrics were performed only twice per week to allow sufficient recovery time between workout sessions. This is the standard training format followed by power athletes — shot putters, discus throwers and high jumpers (16, 18).

Verhoshansky introduced plyometrics as a dynamic method of improving power output and explosiveness (21, 22). He promoted the depth jump as the main plyometric drill to increase explosive leg power. Verhoshansky believed that plyometrics should be included with weightlifting in a training program to develop and maintain explosiveness.

The important contribution of plyometrics (jump training) to athletic power production can be seen in the following brief mechanical analysis. In the execution of plyometric drills, kinetic energy is generated and stored within the muscles to be used during the subsequent positive phase in the form of mechanical work, which improves performance (4). When performing plyometrics, the athlete uses the force of gravity to store energy within the muscle structure of the body. This storing of energy is immediately followed by an equal and opposite reaction, using the elastic properties of the muscles to produce a kinetic energy system (21). Chu compares this reaction to compressing a spring, then releasing the downward force and letting it spring up (6). Thus, by using the myotatic stretch reflex of the muscle to produce an explosive reaction, plyometrics is believed to be the link between speed and strength (7, 23).

The vertical jump is a test of hip and thigh power production. In order to jump higher, the athlete must generate more power by increasing the strength and velocity of the muscle contraction. A strength-training program, using the squat as the main exercise, increases the strength of the key muscles involved in the vertical jump (13, 17). Plyometric training drills are believed to develop explosiveness, the ability to use strength as quickly and forcefully as possible (23). By bridging the gap between strength and speed, the athlete can optimize power production. The purpose of this research was to investigate the effectiveness of three training programs — S, P and SP — in improving hip and thigh power production as measured by vertical jump, and to discover which program optimizes hip and thigh power production.

METHODS

Forty-eight male subjects, enrolled in a strength-training class at Utah State University, volunteered as subjects for this study. The subjects were intermediate lifters, with a minimum of one year of recreational lifting experience and little or no exposure to specific power training or plyometrics. The use of subjects for this study was approved by the Human Subjects Committee at Utah State University. An informed consent form was read and signed by each subject before participation.

Hip and thigh power production was tested before and after training with the vertical jump test (8). Reliability of the vertical jump test is reported at 0.93 (14). The subjects were tested in random order. Three trials were given, with the best score recorded for subsequent statistical analysis. Subjects also were tested before training for a one-repetition maximum (1 RM) parallel squat according to the technique described by O'Shea (17). The squat score was

Table 2. Plyometric Program

Warm-up
Jog 200 m
Back and leg stretch 5 min

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Depth jump*	3 x 10/51	3 x 10/76	3 x 8/89	3 x 8/102	2 x 8/102	2 x 6/114
Double leg hop**	3 x 15	3 x 15	3 x 15	3 x 15	2 x 15	2 x 15
Split squat						
Walking**	3 x 15	2 x 15	1 x 15	1 x 15	1 x 15	Rest
Standing***	1 x 10	2 x 10	3 x 8	3 x 8	3 x 6	Rest

All workouts performed Tuesday and Friday
*Sets x reps at box height (cm)
**Sets x distance (m)
***Sets x reps

used to establish training intensity in the squat. It was not used for post-data analysis. Three spotters were present at all times to monitor the lifters' safety. Belts and knee wraps were used by all lifters.

Subjects were ranked highest to lowest according to their vertical jump scores, divided into groups of four by rank, and randomly matched to one of four groups: squat (S), plyometric (P), squat-plyometric (SP), or control (C). To standardize training procedures, a one-week orientation took place consisting of two sessions in which the methods and techniques of the training programs were demonstrated and discussed.

The S group's training load was determined for each workout using a set percentage of each subject's pre-training parallel squat 1 RM. Subjects started with four sets of eight repetitions at 70 percent of 1 RM during week one, and progressed to two sets of two repetitions at 100 percent of 1 RM during week six (Table 1). The subjects performed two training sessions per week consisting of a heavy day (Tuesday) and a light to medium day (Friday). This enhanced the subjects' recovery time. All squats were executed to the parallel position.

Subjects in the P group performed three plyometric drills — depth jumps, double-leg hops and split squats. Depth jumps were executed as described by Yessis and Hatfield (23), with the athlete stepping off a specifically constructed box onto a wrestling mat, with an immediate jump upward. Depth jump height started at 50.8 centimeters and progressed to 114 centimeters in week six (Table 2). Double-leg hops were executed as described by Chu (6), for a distance of 15 meters. Split squats were executed as described by Chu (6).

Plyometric peaking cycles were based on the principle of periodization, with the volume decreasing as the intensity increased. Subjects were encouraged to perform each drill with maximum intensity, emphasizing a fast switch from eccentric to concentric contraction for optimum quickness off the ground. A prescribed number of sets and repetitions were executed (Table 2), with one to two minutes of rest between sets. Training took place two days per week, on Tuesday and Friday.

Subjects in the SP group performed squats and plyometric drills in the prescribed manner (Table 3). On the heavy lifting day (Tuesday), the squats were performed first, while on the light day (Friday), plyometrics were first. Due to the possibility that time and workloads could be responsible for any mean differences rather than treatment effects, consideration was given to the equalization of volume and intensity in the training schedules. The SP group performed at the same intensity as the other training groups, but the volume of work was reduced by 25 percent (10).

With the equalization in squat volume, the total training of the SP group was still somewhat greater than the S group. However, one of the primary considerations in writing the training protocols for the SP and S groups was to duplicate, as closely as possible, a typical strength/power program as followed by collegiate long jumpers and

Table 3. Squat-Plyometric Program

Warm-up

Back and leg stretch	5 min
Squat 1 x 10	60 kg
10-15 kg jumps	1-5 reps up to workout weight

Squat Program	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Tuesday	3 x 8 70%	3 x 6 80%	2 x 5 85%	2 x 3 90%	2 x 2 95%	2 x 2 100%
Friday	2 x 8 50%	2 x 8 60%	2 x 8 70%	1 x 8 70%	1 x 8 70%	Rest

Sets x reps at % of 1 RM

Plyometrics	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Depth jump*	3 x 10/51	3 x 10/76	3 x 8/89	3 x 8/102	2 x 6/102	2x 4/114
Double leg hop**	2 x 15	3 x 15	3 x 15	3 x 15	2 x 15	1 x 15
Split squat						
Walking**	2 x 15	2 x 15	1 x 15	1 x 15	1 x 15	Rest
Standing***	2 x 10	2 x 8	3 x 6	2 x 6	2 x 6	Rest

Plyometrics performed Tuesday and Friday
*Sets x reps at box height (cm)
**Sets x distance (m)
***Sets x reps

competitive powerlifters, respectively. Anything less would not have adequately tested the research hypothesis.

Results

A 4 x 2 one-way analysis of variance (ANOVA) was used to determine the difference in pre- and post-training test score means for vertical jump between the C, S, P and SP groups. Alpha level was set at 0.05. ANOVA procedures demonstrated a significant value ($p = 0.0001$) for the treatments (Table 4). A Fisher's LSD post-hoc test was used to determine where these differences occurred. SP training was significantly better ($p < 0.0001$) than either S or P training alone in increasing hip and thigh power production as measured by vertical jump. S and P groups, compared with each other, showed no significant difference in improving hip and thigh power production ($p = 0.698$). S and P training were both significant compared to the C group ($p = 0.019$, $p = 0.007$, respectively). Examination of the pre- and post-training test mean scores shows that the S group increased an average of 3.30 centimeters in vertical jump, the P group increased an average of 3.81 centimeters and the SP group increased an average of 10.67 centimeters.

Discussion

The results of this investigation are in agreement with previous studies (2, 5, 9, 19, 20), showing that a combined program of weightlifting and plyometrics can significantly increase vertical jump ability. As previously indicated, one of the primary limitations of these earlier studies was the

Table 4. Analysis of Variance Results

Source	SS	DF	Var. Est.	F-ratio	p value
Among	109.23	3	36.41	21.67	0.0001
Within	73.92	44	1.68		
Total	183.15	47			

Table 5. Comparison of Studies for Vertical Jump

Blattner/Noble (2)	VJ Improvement (cm)
Isokinetic leg press group	1.94
Plyometric group	2.05
Present Study	
Squat group	3.30
Plyometric group	3.81
Squat-plyometric group	10.67

use of conventional weight training. This makes it extremely difficult to apply the results to athletes involved in power sports. In this study, which used athletic strength training, it is possible to formulate some basic assumptions as to what extent the findings may be applied to power sports training. Of course, even here there is cause for guarded optimism, as the subjects were non-athletes.

As could be expected, the results of this study illustrated that a parallel squat program by itself has a significant effect in increasing hip and thigh power as measured by the vertical jump. O'Shea (17) believes that the dynamic nature of the parallel squat is highly conducive to enhancing neuromuscular efficiency (e.g., facilitating the stretch reflex). This in turn allows for excellent transfer of power to other biomechanically similar movements that require a powerful thrust from the hips and thighs, such as vertical and horizontal jumps.

Plyometric training alone, as evidenced by this study and others such as Blattner and Noble (2) and Bosco (4), can also have a significant effect in increasing hip and thigh power specific to vertical jumping. Bosco believes this results from enhancing motor unit recruitment and improving the muscles' ability to store kinetic energy within the elastic components of the muscle (4). This may enhance hip and thigh power by increasing the explosive capabilities of the athlete. The transfer of this explosiveness to activities other than the vertical jump needs further investigation.

Finally, this study illustrates that a combined athletic parallel squat and plyometric training program increases hip and thigh power production significantly more, as measured by the vertical jump, than either a separate squat or plyometric program. Conclusions can be drawn as to the type of training required by power athletes by comparing the results of this study to Blattner and Noble, who used an isokinetic leg press machine instead of the dynamic parallel squat (2). Keep in mind that the subjects in both studies made significant improvement in vertical jump ability (Table 5).

This study clearly illustrates the close working relationship between neuromuscular efficiency (e.g., multiple fiber recruitment and facilitating the stretching reflex) and dynamic strength performance. With reasonable confidence, it can be said that parallel squats are conducive to the development of hip and thigh strength, while the simultaneous application of plyometrics permits effective use of this strength to produce explosiveness in sports or events demanding speed and quickness. In other words, the role of plyometrics is to facilitate the neuromuscular system into making a more rapid transition from eccentric to concentric contraction, whereby maximal ballistic force is generated. This lends support to the theories of Gambetta (9), O'Shea (18) and Yessis and Hatfield (23), who believe that plyometric training is the link between speed and strength.

Practical Applications

Out of necessity, athletic strength and speed training must focus on optimizing the power flow of linear and rotational energy transfer that occurs during the transition from eccentric to concentric muscle contraction. To train and enhance this transition phase requires a complex athletic weight-training and plyometric program as used in this study. Such a program challenges an athlete to develop and apply strength through a wide range of multiple joint movements at progressively higher velocities. It trains the athlete to think in terms of applied strength, speed and technique. A high magnitude of explosive strength is the result.

Athletes who stand to gain the most from a combined training program are those competing in instantaneous power events, such as field events, sprinting, hurdling, basketball, volleyball, alpine ski racing and sprint bike racing. Plyometrics can contribute the most to improve power production during the strength and power cycle, as well as during the peak power cycle and the peak competitive cycle, but at a greatly reduced volume. In using a combined squat-plyometric program, remember that to a great extent, neuromuscular adaptations occur early in a training cycle (within the first four weeks). Caution should be taken to avoid overtraining and injury. This means closely monitoring the athlete's response to training intensity, which is progressive from cycle to cycle, and providing sufficient recovery time between workouts.

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