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Original Article

The effects of an 8 weeks plyometric training program or an explosive strength training program on the Jump-and-Reach Height of male amateur soccer players

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Abstract:
The purpose of this study was to investigate the effect of systematic beach volleyball training and competition on The purpose of this study was to compare the effectiveness of an in-season plyometric training program or an explosive strength training program on vertical jump height of male amateur soccer players. Twenty-one (n=21) volunteer male amateur soccer players were randomly assigned to one of three exercise groups: plyometric training program, explosive strength training program, and plyometric exercises with explosive strength training. The plyometric exercises consisted of the depth jump, split squat jump, elastic jump, and horizontal and vertical jump patterns. The explosive strength training consisted of the leg press, knee extension, and parallel squat. All groups were permitted to participate in regular soccer training. The 3 groups completed their training twice a week for eight weeks. Subjects were tested prior to (pre-test), at four weeks (mid-test), and at eight weeks (post-test). A 3x3 analysis of variance with repeated measures for three levels of test revealed a main effect for training condition with the plyometric exercises and explosive strength training condition different from the other two training conditions. A 2X3 ANOVA with repeated measures for two levels of tests revealed that all conditions of training improved vertical jump height. It was concluded that plyometric training, explosive strength training, or a combination of both can be used to improve vertical jump height during a soccer season for amateur soccer players.
Key words: Choice of exercise, elastic energy, jump exercises, program design, stretch-shortening cycle (SSC),weight exercises.

Introduction

Vertical jumping is important in a variety of sports. In many sport situations, jumping ability may determine the success of failure of a competition. Superior, jumping ability is a skill that athletes may develop, in part, through specific power, speed, and strength training. Strength coaches use a variety of training methods (e.g., isotonic, isokinetic, and isometric training) to increase vertical jumping ability. Recently, plyometric training has been suggested to provide the speed and explosiveness needed to best improve vertical jumping ability (Von Duvillard et al., 1990). The capacity of soccer players to produce varied forceful and explosive actions such as jumping highly influences soccer match performance (Reilly et al., 2000). The capacity to repeat explosive bouts is an important determinant of player performance (Stroyer et al., 2004). Training for maximal strength has been suggested to play a major role in improving explosive actions as a result of an increased force availability (Cronin et al., 2000).

Plyometrics, with its Greek derivative, comes from "plythein", which means to increase and "metric", which means to measure (Wilk et al., 1993). A plyometric maneuver is involved of developing eccentric muscle tension (lengthening) prior to the concentric contraction (shortening) so that the stored elastic energy can be utilized to gain maximal speed of shortening with power while performing an explosive movement. Plyometric training enhances both neural and elastic aspects of the stretch-shortening cycle, such as the squatting motions before soccer players' leap into air. "Plyometric conditioning" is a term used to describe exercise drills that consist of leaps, bounds, skips, hops, and jumps down from and up to boxes, done with rapid explosive movements (Duda, 1988).

Plyometric exercise tries to combine the natural physiological SSC characteristics in the muscles with strength and power to create a truly explosive movement. Plyometrics exercise focuses on training the period of time between the eccentric and comentric phases (Brown, 2007).

Plyometric training does provide such training stimuli and has shown evidence to improve explosive actions in pubertal (Brown et al., 1986; Matavulj, 2001). Also, these studies demonstrated the benefits of a plyometric training program in pubertal boys during a basketball season, suggesting that in season specific training might be necessary to maintain of increase the explosive actions ability.

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Three phases of plyometric exercise have been identified including: the eccentric phase, the amortization phase, and the concentric phase. The eccentric phase is the mental preparation phase with its duration depending upon the desired stretch stimulus. If the eccentric stretch stimulus phase duration is too long, no improvement in explosive power is observed. The amortization phase occurs when the muscle converts nervous system input into the physical work. The amortization phase is the time between the eccentric and concentric components of plyometric activity. This phase must be of a short duration to achieve the optimal power in the plyometric activity. The concentric phase occurs with the concentric muscle contraction which should be more explosive with the previous stretch occurring during the eccentric phase. The nervous system is also proposed to assess the effects of the stretch-shortening cycle to optimally prepare the muscle for the second repetition of the plyometric maneuver (Wilk et al., 1993; Chu, 1998).

The three general classifications of modes of strength training are isometric, isotonic, and isokinetic training. Isometric exercises occur when muscle generates tension with no movement. Isotonic exercise is divided into concentric contractions and eccentric tensions. During both concentric and eccentric tensions, the muscle is moving. The muscle shortens with concentric contractions and lengthens with eccentric tension. Isokinetic tension occurs with the muscle generating the same tension throughout its range of motion at a constant velocity of shortening (Fleck and Kraemer, 2004; Brown, 2007).

Doing explosive exercises will result in the ability to produce force more rapidly. The ability to produce force more rapidly can be especially advantageous for athletes. Sports such as basketball, volleyball, and soccer all involve explosive, powerful movements. If the individual trains using methods that decrease the time to perform a movement, power output increases (Fleck and Kraemer, 2004). That is, they require the athletes to move very quickly and forcefully in order to jump, accelerate, or defend against an opponent. For optimal performance, specific exercises to improve leg power can be performed (Brown et al., 1986). Jumping (explosive action) is a necessary element for success in soccer and has to be trained independently from aerobic power with an optimal training program. Sport specific training techniques may also be used for the development of jumping power to improve vertical jump height.

To achieve optimal jumping ability, the musculature of the lower limb and hips can respond to a training stimulus by improving muscular power, although traditional strength training programs do not usually incorporate plyometric training. Athletes who participate in sport activities such as basketball and soccer, which require jumping ability, may benefit by using plyometric exercises as a part of their regular training regimen (Hakkinen 1993; Boyle, 2004; Hannam et al., 1988).

The aim of this study was to determine the precise effect of the plyometric training program (PTP), or the explosive strength training program (ESTP), or a combination of both on vertical jump height in amateur soccer players.

It was hypothesized that, there was no difference in jump-and-reach height of male amateur soccer players who trained using plyometric exercises, explosive strength training, or a combination of both.

Method

Research Design

This study examined the ability of a short-term PTP or an ESTP or a combination of both to improve the jumping height during the in-season.

Twenty-one volunteer male subjects were randomly assigned to one of three exercise groups: plyometric training program (PTP) (n=7), explosive strength training program (ESTP) (n=7), and PTP with ESTP (n=7). The PTP consisted of the depth jump, split squat jump, elastic jump, and horizontal and vertical jump patterns (Boyle, 2004; Chu, 1998; Hannam et al., 1988; Pound, 1990). The ESTP consisted of the leg press, knee extension, and parallel squat with a load of 80% of one repetition maximum (1-RM) (Brown, 2007; Hakkinen, 1993). Three sets of 10 repetitions for the leg extensor muscles were performed at the highest possible velocity of shortening (Blattner and Noble, 1979).

The plyometric jump exercises with explosive strength training group were alternated with alternate weeks of PTP and ESTP. The jump-and-reach test was administered prior to training (pre-test), at four weeks (mid-test), and at the end of eight weeks of training (post-test).

Participants

Twenty-one male subjects who denied prior of lower extremity injuries within the last year or experience with plyometric training volunteered to be subjects in this study. Subjects were all male amateur soccer players. Subjects were between 15 and 19 years of age (mean: 17.1 ± 1.1). All subjects participated in conditioning programs for at least one year prior to the study. Subjects received both written and verbal instructions concerning testing procedures and possible risks. Each subject and their parent or designated guardian signed a written informed consent prior to participation in the study. Coaches of soccer teams granted permission for the investigator to approach potential subjects to ask for volunteers to participate in this. The anthropometric characteristics of the participants are presented in Table 1.

Procedures

This section describes the performance test that was used to measure jump-and-reach height.

Jump-and-Reach Test: The jump-and-reach test was used to measure jumping ability of the athletes (Blattner and Noble, 1979; Brown, 2007). A strip of paper was taped to the wall from floor to ceiling. A graduated scale in feet and inches was positioned next to the strip of paper. Subjects were instructed to rub chalk on one hand and stand 3 in. behind a line in front of the wall, with their feet shoulder width apart. Subjects then performed the jump-and-reach test attempting to jump as high as possible while touching the paper with their chalked hand. Subjects completed six trials with a 30-s rest between each trial (Blattner and Noble, 1979). The mean of jumps 3 through 6 were used as scores to compare pre-test, mid-test, and post-test values.

Plyometric Training Program (PTP)

This section describes the plyometric and explosive strength exercises that were performed throughout the study. The plyometric exercises that were performed were chosen from the Jump Training Program and a plyometric workout for basketball and soccer (Boyle, 2004, Chu, 1998; Hannam et al., 1988; Pound, 1990). Plyometric jumping exercises consisted of depth jump, squat split jump, jumping over objects, and horizontal and vertical combination jump patterns. The training group was given verbal instructions, illustrations on technique, demonstrations, and completed a full practice testing session prior to beginning date of collections.

Depth Jump. The subject began the depth jump by standing on a box. The subject then stepped off the box and upon landing on the ground, pushed up and jumped as high as possible with both feet. Three sets at 10 repetitions were performed of the depth jump by the subject (Brown, 2007).

Split Squat Jump. The subject began the squat split jump in a semi-squat position. The subject jumped using a double arm swing with legs straight. At the peak of movement, the subject spread his legs and reached for his toes. Upon landing, the sequence was repeated without hesitation for 10 repetitions. Three sets of the squat split jump were performed (Chu, 1998; Hannam et al., 1988).

Elastic Jump. Six chairs were arranged in two rows with 3 ft between each chair and 2.5 ft aisle between the rows. The backs of the chairs were situated so that they were facing the rows were staggered so that the space between chairs was 1.5 ft. A 1/4 in. wide elastic band was attached to the seat base of each chair to form a zig-zag pattern across the aisle. The subject jumped sideways (i.e. over-back-over) over the elastic band immediately going to the next crossing and repeating the sequence. The subject continued the jump until he reached the end of the aisle. Each pass through the aisle was one set. The subject performed either two or three sets (Hannam et al., 1988).

Horizontal and Vertical Jump Patterns. The subject performed a combination of jump patterns. The first combination of jump patterns consisted of starting in a set position, jump forward, jump to the right, jump to the left, and jump forward again. The subject then immediately switched lead side direction for the next combination of jumps. Each eight jump combination was considered one set. Subjects performed two sets. The second combination jump pattern consisted of starting in a set position, jumping forward jumping to the right, jumping forward, jumping to the left, and jumping to the right. The subject immediately switched the lead side direction for the next combination. Each 10-jump combination was considered one set. Subjects performed two sets (Pound, 1990). Because running and training both horizontal and vertical components, it seems to make sense that both horizontal and vertical jump training would contribute to improvement in both activities (Chu, 1998).

Explosive Strength Training Program (ESTP)

Subject performed three sets of 10 repetitions of the leg press, knee extension, and parallel squats with a load of 80% of 1-RM. Each repetition was performed with the highest velocity possible (Blattner and Noble, 1979; Hakkinen, 1993; Flek and Kraemer, 2004). Explosive high- velocity training has demonstrated greater improvements in rate of force development and explosive actions in comparison with traditional weight training methods for maximal strength (Hakkinen et al., 1985; Wilson et al., 1993; Brown, 2007; Fleck and Kraemer, 2004). Sports such as soccer do not require as much absolute strength, so two days plyometric and explosive strength training program can be used (Boyle, 2004).

Training Procedures

Subjects were randomly assigned to one of three experimental groups by drawing numbers from a hast. Group I performed exercises from the PTP, Group II from the ESTP and Group III from the PTP and ESTP.

The training protocol for Group I, consisted of depth jumps, split squat jumps, elastic jumps, and vertical and horizontal jump patterns. Three sets of 10 repetitions with a 1-min rest between sets were performed.

Due to the difficulty of the elastic jump, subjects performed either two or three sets with a 3-min rest between each set (Hannam et al., 1988).

The training protocol for Group II, consisted of the leg press, knee extension, and parallel squats. Three sets of 10 repetitions per set with a load of 80% of 1-RM at maximum velocity were performed. The rest periods were 1 minute of rest between exercises and 3 minutes between the sets.

Training protocol for Group III, combined the plyometric training program and the explosive strength training program. The subjects of group III performed one day of the week (Tuesday or Wednesday) the PTP and the other day the ESTP (Thursday or Friday). The recovery period between the sessions was at least 2 days.

Subjects received written and verbal instructions concerning testing procedures and possible risks. Subjects trained twice a week for eight weeks using their assigned training methods. Each training session began with warm-up drills, stretching, and soccer play. Subjects were advised to wear loose fitting clothing and supportive athletic footwear. The same footwear was used for the jump-and-reach test.

All subjects were instructed not to perform other lower extremity plyometric drills or strength training during the study. All subjects continued to participate in their soccer training.

Data Collection

Prior to the eight-week study period, subjects were pretested for their maximal vertical jump-and-reach height. The jump-and-reach height was also measured at four weeks (mid-test) and at the end of eight weeks of training (post-test).

Statistical Analysis

All values were calculated, as mean and standard deviation (S.D). A 1X3 analysis of variance (ANOVA) was performed for age, height, and body weight. A 3X3 ANOVA with three levels of training (plyometric training, explosive strength training, and plyometric jumping with explosive strength training) and with repeated measures analysis of variance for three levels of test (pre-test, mid-test, post-test) were performed for the jump-and-reach test. A 2X3 ANOVA with repeated measures for two levels of test (difference in mid-test and pre-test scores and post-test and pre-test scores) was performed. The SPSS for Windows, was used to complete the analysis. The level of significance was set at $p < 0.05$.

Results

There were no differences in mean age or body weight of the subjects (Tables1, 2). The 3 X 3 ANOVA revealed that an initial difference between groups for jump-and-reach height existed (Tables 3, 4). The jump-and-reach height for the plyometric training program with explosive strength training group was significantly greater than for the other two groups of subjects (group means: 15.2 ± 1.3, 15.2 ± 1.9, and 16.5 ± 2.4 in. for plyometric jumping exercises, explosive strength training, and a combination of the two training regimens, respectively).

Table 1. Anthropometric characteristics of the three groups (mean ± S.D.)

Group	Age, yrs.	Height cm	Weight, Kg
Plyometric Training	16.7 ± 1.1	171.5 ± 7.4	59.6 ± 6.2
Strength Training	16.9 ± 1.1	174.8 ± 7.6	65.8 ± 9.0
Plyometric/Strength Training	16.7 ± 1.1	167.9 ± 8.4	64.5 ± 9.1

Table 2. ANOVA for Age, Height, and Weight.

Variable/ Source	Df	SS	MS	F	P
Age					
Group	2	.1	.05	.04	.961
Error	18	21.7	1.21		
Total	20	21.8			
Height					
Group	2	25.8	12.9	1.38	.278
Error	18	168.6	9.4		
Total	20	194.5			
Weight					
Group	2	719	360	1.11	.352
Error	18	5850	325		
Total	20	6570			

Table 3. Effect of Plyometric Training or Explosive Strength Training on Jump-and-Reach Height of male amateur soccer players.

Group	Pre-Test	Mid-Test	Post-Test
Plyometric	14.7 ± 1.7	15.2 ± .9	15.7 ± 1.3
Strength Training	14.4 ± 1.8	15.4 ± 2.6	15.7 ± 1.3
Plyometric/ Strength Training*	15.7 ± 1.3	16.7 ± 2.8	17.0 ± 3.1

Note. Values are means and the standard deviations of the mean in inches.
* Represents a significant difference (p<.05) from other groups.

Table 4. ANOVA for the Jump-and-Reach Test.

Source	df	SS	MS	F	P
Group	2	59.11	29.56	5.87	.005
Time	2	14.41	2.20	1.41	.213
Time X Group	4	.95	.24	.05	.996
Error	36	29.36	.82		
Total	41	34.77			

Since the differences among subjects in the initial jump-and-reach test were large and the plyometric jumping and explosive strength training group of subjects was different from both the other two groups of subjects, a 2 X 2 ANOVA was performed on the differences in jump-and-reach height between the mid-test and pre-test scores and post-test and pre-test scores. This analysis revealed a significant improvement in jump-and-reach height for all three groups for differences in scores between the post-test and pre-test (1.17 ± .72 in.) while no difference was observed between the mid-test and pre-test (.59 ± 1.05 in.) (Tables 5, 6).

Table 5. Effect of PTP or ESTP on the Difference in the Jump-and- Reach Height of amateur soccer players .

Group	Mid-Test / Pre-Test	Post-Test / Pre-Test*
Plyometric	.46 ± 1.20	1.01 ± .70
Strength Training	.97 ± 1.00	1.30 ± .83
Plyometric/ Strength Training	.34 ± .95	1.20 ± .63

Note: Values are means and standard deviations of the mean in inches.
* Represents a significant difference (p<.05) between the pre-test and post-test scores.

Table 6. ANOVA for Difference in Jump-and-Reach Test.

Source	df	SS	MS	F	P
Group	2	1.37	.69	.84	.44
Time	1	3.54	3.54	4.35	.04
Time × Group	2	.49	.25	.30	.74
Error	36	29.36	.82		
Total	41	34.77			

Discussion

The difference between mid-test and post test compared to the pre-test jump-and-reach height increased with all three training regimens. These data are in agreement with Blattner and Noble (1979) who showed that vertical jump improved with either isokinetic or plyometric training.

Wilson et al. (1993) also found improvement in countermovement jump and static jump of plyometric-trained, optimal power, and strength-trained subjects. Wilson et al. suggest that an optimal training strategy for dynamic athletic performance is a cross between traditional strength training and plyometric training. Similarly, Clutch, et al. (1983) found that training programs incorporated with strength training improved jumping ability of subjects.

One study by Adams et al. (1992) found that those who trained using a combination of squat exercises and plyometric exercises increased their vertical jump significantly (10.67cm) over those who trained on squats (3.30 cm) and plyometrics (3.81 cm) alone over a six week period.

Also, research has shown that the combination of resistance and plyometric training yields greater results than either alone (Kotzamanidis et al., 2005; Faturos et al., 2000; Fleck and Kraemer, 1986; Blakey and Southard, 1987). A study by Lyttle et al. (1996), has suggested that athletes who perform both heavy weight lifting and plyometric exercises “may enhance the use of elastic strain energy, or facilitate the stretch reflex to a greater extent than does maximal power training.”

A few studies of trained athletes (basketball and soccer players) however, have shown positive improvements in motor performance (Diallo et al., 2001; Matavulj et al., 2001; Wagner and Kocak, 1997). Thus, players can use plyometric exercises to make changes in motor performance.

The competitive season may decrease explosive performance of athletes if the strength training regimen is insufficient to continue to develop this skill (Hakkinen, 1993). Jump training and strength training may only maintain performance level during the season (Hannam et al., 1988). Basketball and soccer players involve jumping skill and jump exercises which may not add significantly to the skill learned in practice, limiting the ability to see improvements with plyometric training during a season (Clutch et al., 1983). The findings of this study suggest that the plyometric jump exercises and the explosive strength training were sufficient to induce improvements in vertical jump height.

The next step would be to design a specific PTP and ESTP for soccer players according to age and to their training backround. Plyometric training can be adopted to every sport, and the players should do exercises that help them to enhance the movement they perform. By performing certain soccer movements in plyometric training players can decrease movement time and become more powerful (Chu, 1998).

Decision on hypothesis

Based on the results of this study the following decision on the hypothesis was made. Since there was a difference between the differences in the pre-test and post-test scores of the jump-and-reach height of male amateur soccer players who trained using either plyometric training exercises, explosive strength training, or a combination of both, the hypothesis was rejected.

Conclusions

Based on the results of this study, the following conclusion was made:

Plyometric training, explosive strength training, or a combination of both can be used to improve vertical jump height during a soccer season for amateur soccer players. The PTP, the ESTP or the combination of them did increase the jumping ability for players, so they can win aerial challenges

Recommendations

Based on the results of this study, the following recommendations are made:

1. Use integrated electromyography to determine the proportion of neural and muscular adaptations to plyometric training.
2. Increase the level of explosive training beyond that which is traditionally used for soccer training.
3. Determine the percentage of skill improvement vs. strength gain with plyometric training or explosive resistive training.

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