Comparing the Effects of Plyometric Training with and without Vessel Occlusion on Electromyographic Parameters

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ABSTRACT

Purpose: Doing plyometric training with and without the vessel occlusion is an effective practice for rapid increase of muscles strength their hypertrophy. We evaluated the effects of plyometric training with and without the vessel occlusion on electromyographic parameters.

Methods: In this quasi-experimental study, 22 females were selected through convenience sampling method. They were randomly categorized into 2 groups of plyometric training enforcing blood current limitation (30% 1RM) and plyometric training without enforcing blood current limitation (80% 1RM). The volunteers undertook 3 days per week training for 8 weeks. Before and after training, electromyographic parameters of the participants were evaluated. Analysis of covariance (ANCOVA) was used to evaluate changes in maximal elbow extension and flexion forces from pre-exercise session to the post-exercise session. The level of significance was set at $P \leq 0.05$.

Results: Plyometric training with vessel occlusion increased electromyographic parameters compared to the plyometric training without the vessel occlusion.

Conclusion: Plyometric training with enforcing current limitations by low intensity is similar to plyometric training by high intensity on electromyographic parameters. Therefore, this kind of training may replace classic plyometric training.

Keywords:

Plyometric training, Enforcing current limitations, Electromyographic parameters

1. Introduction

Among recently developed training systems, exercises targeting physical preparation have always received the most attention. It is the direct outcome of muscular system dominance over other systems in athletic performance. Plyometric training is based on a collection of mechanical and physiological capabilities of the muscle [1]. This kind of training is applied in several stages of preparation (prior

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to and during the season) in most athletic fields, attracting athletes' attention over the past decade [2]. Thus, it is of great significance to consider the effects of plyometric training and the mechanisms enhancing the strength and speed of skeletal muscles. Plyometric training consists of moves which start with a swift muscle stretch, followed by an immediate contraction [3]. Most studies describe plyometric training as containing activities like jumping, hopping, ball-throwing, skipping, obstacle jumps, while according to other studies, it comprises resistance activities, a harmony of the leg with other limbs, speed skills, speed sports, throwing, power, and balance [4]. As a result, a good way to improve plyometric training is to use resistance training [5].

According to the American College of Sports Medicine, for a noticeable muscles' volume and strength, the person must increase at least 70% in the maximum frequency of an exercise; otherwise, the increase in the volume and strength of the muscles is not likely to happen, and any smaller intensity will hardly ever lead to hypertrophy and gaining strength [6]. It has recently been noted, though, that strength exercise with low intensity (20%-50% of a maximum frequency) can bring about increase in the volume, power, and capability of the muscles if accompanied by a limitation in blood flow [7-8]. The increase in metabolism might well be the main cause of the observed results with pressure from outside. The effects of strength training together with limitation in blood flow seems to be an outcome of the consistency between the blood occlusion (external cuff pressure), the muscle's electric activity (rise in signaling electromyography), and exhaustion level (which could be continuous) [9]. Carvalho et al. studied 12 handball players aged 21 during 12 weeks of strength training accompanied by plyometric exercises and found a significant rise in their records in squat jump, long jump, and 40 subsequent jumps [10].

Signaling electromyography is a method to assess and record physiological properties of the muscles during rest time and exercise [11]. Some researchers propose that signaling electromyography can provide an index of muscle damage if the motor units are selected. Among common parameters that can be used to study exhaustion and muscle damage are the mean of frequencies and the frequency power, which are reflective of electromyography frequencies [12, 13]. Electromyography frequencies can provide researchers with helpful information regarding the speed of neurological conductivity and affectedness of motor neurons during physical activity. Plyometric training and the changes in the neuromuscular performance of muscular tissue can be a good source of benefit for athletes and a prompt base for studying neuromuscular mechanisms [14]. In this regard, Chimera et al. studied the effect of plyometric training on the activation of the muscles and the performance of lower extremity during jumping activities with the use of electromyography and concluded that the strength and electromyography activities of abductor and adductor as well as quadriceps and hamstring muscles had significantly increased [15]. Yamada et al. (2004) studied the activities of motor units in 6 male subjects, using signaling electromyography, and oxygen absorption during plyometric training with 30%, 50%, and 70% the maximum conscious muscular contraction and without blood occlusion. A significant relationship was then found between signaling electromyography and the average power in the 30% and 50% conscious contraction with blood occlusion [16].

It is documented that physical exercise with current occlusion is a healthy and secure training method, which can be more helpful than physical exercises without occlusion. This study aimed at evaluating the changes and adaptations made with either of the 2 training methods particularly on the biceps and triceps muscles through electromyography to better understand how much the muscles been affected in response to plyometric training with and without occlusion. The findings could be also used when prescribing either or both of the methods for rehabilitation. As a result, the researchers would like to compare the effects of plyometric training with and without current occlusion on electromyographic indices of tennis players' arms.

2. Materials and Methods

Participants

This is a quasi-experimental study of the functional type. The current study was conducted at Bojnourd University of North Khorasan, in 2015. The study population comprised all female tennis players that enrolled in academic year 2014-15 at this university. The sample consisted of 22 semi-professional female tennis players from Bojnourd City between the ages of 18-30 years. These subjects were selected through convenience sampling method. The inclusion criteria were as follows: being qualified according to a health questionnaire, not using drugs, being non-smokers, being of the same phenotype, and not having participated in any training sessions for the past 2 months. At first, the subjects were familiarized with the nature and the procedure of the study. They had also the right to leave the experiment whenever they desired without giving any explanations.

Then, the volunteered subjects filled in the admission forms. Next, they were randomly assigned to 2 groups of plyometric training with and without blood occlusion, each comprising 11 subjects. Two groups of subjects were compared using pretest and posttest results.

To assess the subjects' bodily features, we used a Seca height meter with a sensitivity of 5 mm, a Mabis tape meter with an exactitude of 5 mm to measure their circumference at waist and hip, and a bioelectrical impedance (S. Korea/In body-720) to calculate body fat and weight with the exactitude of 100 g. All measurements were taken at least after 4 hours of fasting so that the subjects' bladders, stomachs, and intestines would be evacuated.

Procedure

Muscular strength estimation test was conducted based on Berzisky formula to calculate muscular strength (training intensity). Based on this test, the subjects selected a weight which they could lift 10 to 12 times till they got tired. Their maximum strength was calculated according the following formula:

One maximum repetition=displaced weight (kg)/(0.0278 x number of repetition to exhaustion)–1.0278

W=body weight (kg), r=repetition before exhaustion [17].

Blood occlusion was done as follows. An 85x6 centimeter compass cuff was used to slow down blood flow and lessen the pressure on the muscle. There was a plastic tube inside it with 2 vessels, one to let air in and the other attached to the barometer. Each individual's cuff pressure was 1.3 times her arm's systolic pressure. This was independently measured for each subject. At the onset of each training session, the current was occluded for 30 seconds with 120 mm Hg pressure; then the pressure was increased by 20 mm and again a 30-second occlusion was applied, then the prssure was released [18].

Regarding electromyographic activities, linear 8-channel electrodes (8 signal-recording and 1 earth electrode) were used to record the activities of biceps and triceps, using a channeled electromyography set produced by Bioelettronica company (EMG amplifier, EMG-16 LISiN-OT Bioelettronica, Torino, Italy, bandwidth 10–500 Hz). The linear electrodes were set on the muscles in the direction of their ligaments. The hair was removed from the point of connection on the skin. Then the skin was rubbed applying slight controlled pressure with the use of fine sandpaper. Some alcohol was then used to clean the skin with the use of cotton. All this was meant to reduce the electrical error.

Training program

The training protocol comprised plyometric exercise (with and without occlusion) three 60-minute sessions per week, for 8 weeks. The plyometric exercise group without occlusion performed 6 moves; throwing the ball over the head, throwing the ball backwards and jumping over the step, taking and throwing the ball while standing still, revolving and throwing the ball, throwing the ball high, and then holding it. Four sets of forwarding were performed, each comprising 8-10 times throwing the ball and 1 minute of rest between every 2 sets. The intensity was 40% to 80% of maximum repetition. To conform to the overload principle, after each 2 weeks, 20% of maximum repetition was added to the training pressure (heavier balls were used with the exception of the last 2 weeks, when the pressure was as much as weeks 3 and 4 so as to retrieve) [19-20]. Just as for the group without occlusion, the training program for the group with occlusion included 4 sets, but their dominant hand hold the cuff for occlusion (the cuff was loosened at the end of the session and fastened again at the beginning of the next session). The intensity was 20% to 30% of maximum repetition (30 repetitions at the first set and 15 ones at the next 3). The rest time was 1 minute between sets and 4 minutes between sessions [19-20].

Statistical analyses

At the final stage of the study, the data were analyzed using SPSS (Ver. 18). Analysis of covariance (ANCOVA) was used to evaluate changes in maximal elbow extension and flexion force from pre-exercise session to the post-exercise session. Analysis of covariance was also used to measure change in time to task failure during sustained elbow extension and flexion. Additionally, ANCOVA was used to compute changes in EMG amplitude of biceps and triceps muscles during maximal elbow extension and flexion before and after training. ANCOVA was also used to compute changes in EMG amplitude of biceps and triceps muscle during sustained elbow extension and flexion.

3. Results

The findings of the experimental and control groups are presented in Table 1. As it can be seen in Table 2, between groups, biceps maximum strength (P=0.038), the electromyographic wave range for biceps during maximum contraction (P=0.001), the electromyographic

Table 1. Participant characteristics at baseline.

Variables	Levene's test					
	Groups	(M±SD)	F	Sig.	t	df
Age (years)	1	25.83±3.90	0.001	0.975	0.397	22
	2	25.16±4.30				
Height (cm)	1	162.83±6.38	0.074	0.788	0.806	22
	2	165.12±7.49				
Weight (kg)	1	62.08±13.31	0.766	0.391	-0.340	22
	2	63.79±11.24				
Body mass index (kg/m^2)	1	23.24±3.95	0.785	0.385	-0.045	22
	2	23.30±2.94				

1. Plyometric group.

2. Plyometric+vessel occlusion group.

Table 2. Comparing electromyography parameters in plyometric training with and without the vessel occlusion.

Variables	Group (s)	Pretest M±SD*	Posttest M±SD*	Variations		
				Percentage of variations	Between groups	
					F	P-value
Biceps maximum strength (mV)	1	28.58±2.09	54.83±7.93	91.84	4.5	0.038‡
	2	35.58±1.40	35.41±1.86	-0.47		
Electromyographic wave range for biceps during maximum contraction (mV)	1	17.80±1.80	21.25±2.1	19.38	21	0.001‡
	2	17.40±1.90	17.41±21.40	0.05		
Electromyographic wave range for triceps during maximum contraction (mV)	1	15.25±1.67	40.08±9.71	162.81	3.8	0.048‡
	2	20.75±1.53	20.16±1.93	-2.84		
Triceps maximum strength (mV)	1	17.40±1.90	21.40±1.7	22.98	36	0.00‡
	2	18.60±1.60	19.65±1.5	5.64		
Contraction breakdown time for biceps (s)	1	101.91±12.53	147.25±9.71	44.49	5.1	0.035‡
	2	118.41±12.48	122.58±10.81	3.52		
Electromyographic wave range for biceps during strength contraction (mV)	1	276.90±23.29	423.18±12.68	52.82	6.8	0.025‡
	2	257.54±14.12	276.18±10.34	7.23		
Contraction breakdown time for triceps (s)	1	90.83±9.68	134.83±9.59	48.44	4.9	0.031‡
	2	11.66±10.85	121.66±10.85	8.95		
Electromyographic wave range for triceps during strength contraction (mV)	1	17.80±1.80	21.25±2.1	19.38	19	0.0032‡
	2	17.40±1.90	17.40±21.40	0		

*Data are presented as mean±standard deviation.

‡The mean difference is significant at 0.05 level.

1. Plyometric+vessel occlusion group.

2. Plyometric group.

wave range for triceps (P=0.048), contraction breakdown time for biceps (P=0.035), the electromyographic wave range for biceps during strength contraction (P=0.001), contraction breakdown time for triceps (P=0.031) and the electromyographic wave range for triceps during strength contraction (P≥0.048) were significant.

4. Discussion

The purpose of the present study was to compare the effects of 8 weeks plyometric training with and without blood occlusion on the electromyographic indices of the arm muscles of tennis players. With regard to the group with blood occlusion, it was found that after the eight weeks maximum muscular strength of the biceps had increased by 91.84%, the electromyographic wave range for bicep muscle during maximum contraction by 19.38%, the electromyographic wave range for triceps by 162.81%, biceps maximum strength by 22.98%, contraction breakdown time for bicep muscle by 44.49%, the electromyographic wave range for bicep muscle during strength contraction by 52.82%, contraction breakdown time for triceps by 48.44%, the electromyographic wave range for triceps during strength contraction by 19.38%.

The findings were consistent with those of Diallo et al. [21], Chimera et al. [15] and Doyle et al. [22]. Diallo et al. [21] reported that short-term plyometric training significantly raised jumping performance. It is assumed that muscular hypertrophy did not take place because of the improved performance of neurological factors. Chimera et al. [15] studied the effects of 6 weeks of plyometric training (2 sessions per week) on muscular electric activity in 20 female athletes. They concluded that the increase in the electromyographic activity in adductor muscles during preparation was significant. Doyle et al. [22] reported a promoting effect of plyometric training on signaling electromyography at the final stage of specialized training and after rugby exercises. Since plyometric training is subsumed to resistance training, it has to follow the principle of progressive overload; hence a smaller amount of exercise as the intensity rises.

EMG (electromyography) is one of the mechanisms leading to the gaining of strength with blood occlusion. Research shows that an increase in the electrical activity of the muscle in strength exercises with blood occlusion and with low intensity is equal to strength exercises without occlusion and with high intensity [23].

Physiologically, exercising with occlusion results in changes in the body [24]. It appears that accumulation of by-products of the first mechanism is related to training with blood occlusion [25]. The increase in blood lactate and muscular cell lactate, which is a result of occlusion, can in turn impose an increase in the growth hormone. Seemingly, a cellular acid environment provokes the release of the growth hormone. Evidence shows that low PH stimulates sensitive neurological activities that are mediated by metabolic receptors of type 3 and 4 afferent ligaments [24]. Therefore, a similar path plays an important role in hypophysis regulating of the growth hormone [23].

There is a consensus over the effectiveness of plyometric training; however, lots of questions regarding the involved mechanisms still have remained unanswered, particularly from the neurological aspect. Measurable neurological parameters such as muscular conduction speed, electromyography, motor unit summon, and Hoffmann reflex can change in response to physical activity. The probable mechanisms for performance improvement are aftermaths of plyometric training, including better use of the elastic energy of the muscle, reduction in the sensitivity of Golgi tendon organ, change in the temporary displacement muscle activation for an improved kinetic efficiency, preferred summon of the quicker motor units, quicker neurological launch (shooting), and stimulation of motor neuron [15, 26, 27]. However, the increase in absolute power and electromyographic activity subsequent to plyometric training is not that much, because the increase in electromyography is due to the changes in the mechanical attributes of tendon-muscle combination and neurological mechanisms which fade away right after training is over [22]. This study has some limitations that need to be acknowledged. A major limitation is the relatively small sample size.

It can be concluded that 8 weeks of plyometric training together with blood occlusion increases the electromyographic wave range of biceps and triceps in women athletes. Therefore, such training can replace other exercises in health and sports programs, which call for power and strength.

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Conflict of Interests

The authors declared no conflict of interests.

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