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REVIEW PAPER

EFFECTIVENESS OF PLYOMETRIC TRAINING WITH BLOOD FLOW RESTRICTION ON EXPLOSIVE POWER IN Taekwondo ATHLETES

Behnam Boobani, Renārs Līcis

Latvian Academy of Sport Education,
Address: 333 Brivibas Street, Riga, LV 1006, Latvia
E-mail: behnam.boobani@lspa.lv, renars.licis@lspa.lv

Abstract

The purpose of this study was to investigate the effects of plyometric training with blood flow restriction on explosive power in Taekwondo athletes. Twenty Taekwondo athletes who were volunteers to participate in the research (under 17 years old, at least 2 years in the provincial league and the minimum red belt), were selected .athletes were randomly assigned into two groups of plyometric exercises (n=10) and BFR group (n=10), for both groups the pre-test the Sargent Vertical jump test was used to measure the explosive power. Then plyometric training program for two groups, including six weeks of practice, each week two sessions selected but in one of the groups before exercise, vascular obstruction was performed in the thigh area by closing an elastic cuff around the thigh muscle in the proximal portion of both legs and a pressure of 120mmHg was used. After the completion of the six weeks protocol and the intervention both the group's subjects were assessed to compare the groups covariance analysis was used (α<0.05). All computations were performed using SPSS software version 19. The comparing of the results of the training process of the experimental group in pre-test and after the post-test showed there was not a statistically significant difference in vertical jump of group that they did plyometric training with blood flow restriction. Neural adaptations such as increased activation and synchronization of motor units have been regarded as important factors for improving maximal power outputfor.

Keywords: *plyometric training, blood flow restriction, Taekwondo*

Introduction

In the past decade, more efforts have been made by coaches and athletes to optimize their exercise strategies to improve their ability. The dynamic performance of athletes has been concentrated and athletes are now doing different drill exercises, as well as explosive exercises are used in a ballistic or plyometric training (Markovic, 2007). Functional movements and athletic success depend on both the proper function of all active muscles and the speed at which these muscular forces are used. The term used to define this force–speed relationship is power. When used correctly, plyometric training has consistently been shown to improve the production of muscle force and power (Godek, 2005). The plyometric exercises are mainly used to increase the power and explosive capability (Madaram, 2011), enhancing the strength and speed of skeletal muscles. Plyometric exercises will not only strengthen the fast twitch fibers but increase their quantities inside of muscles. Muscles contract quicker when fast twitch fibers are stronger. These exercises also boost speed and power by empowering the nervous system. The stretch–shortening cycle (SSC) involves three distinct phases: Phase I is the eccentric phase, which involves preloading the agonist muscle group(s). During this phase, the series elastic component (SEC) stores elastic energy, and the muscle spindles are stimulated. As the muscle spindles are stretched, they send a signal to the ventral root of the spinal cord via the Type IA afferent nerve fibers. To visualize the eccentric phase, consider the long jump. The time from touchdown of the foot to the bottom of the movement is the eccentric phase. Phase II is the time between the eccentric and concentric phases and is termed the amortization (or transition) phase. This is the time from the end of the eccentric phase to the initiation of the concentric muscle action. There is a delay between the eccentric and concentric muscle actions during which Type IA afferent nerves synapse with the alpha motor neurons in the ventral root of the spinal cord. The alpha motor neurons then transmit signals to the agonist muscle group. This phase of the SSC is perhaps the most crucial in allowing greater power production; its duration must be kept short. If the amortization phase lasts too long, the energy stored during the eccentric phase dissipates as heat, and the stretch reflex will not increase muscle activity during the concentric phase. Consider the long jumper mentioned earlier. Once the jumper has touched down and movement has stopped, the amortization phase has begun. As soon as movement begins again, the amortization phase has ended. The concentric phase, phase III, is the body's response to the eccentric and amortization phases. In this phase, the energy stored in the SEC during the eccentric phase either is used to increase the force of the subsequent movement or is dissipated as heat. This stored elastic energy increases the force produced during the concentric phase movement beyond that of an isolated concentric muscle action (Bardis 2013). In addition, the alpha motor neurons stimulate the agonist muscle group, resulting in a reflexive concentric muscle action. The efficiency of these subsystems is essential to the proper performance of plyometric exercises. Again, visualize the long jumper. As soon as movement begins in an upward direction, the amortization phase has ended, and the concentric phase of the SSC has begun. In this example, one of the agonist muscles is the gastrocnemius. Upon touchdown, the gastrocnemius undergoes a rapid stretch (eccentric phase); there is a delay in movement (amortization phase), and then the muscle concentrically plantar flexes the ankle, allowing the athlete to push off the ground (concentric phase). For some time, the Blood Flow Restriction (BFR) has been introduced. In this way, the flow of the blood entering the active muscle during an exercise is limited by closing the cuff (tourniquet) or flexible rubber, around the proximal portion of the arm or thigh (Sato, 2005). Blood Flow Restriction has been observed to result in skeletal muscle hypertrophy (Yasuda, 2010) increased strength (Karabulut, 2007).Taekwondo has evolved into a modern-day Olympic combat sport. From a physical conditioning perspective, the goal of Taekwondo training is to prepare competitors to effectively manage both the physical activity and the physiological demands of combat. This approach to conditioning requires detailed knowledge of both the physiological demands of competition and the physical capabilities of the competitors (Casolino E, 2012). In championship combats, competitors perform brief periods of fighting activity [attacks] (1–5s) interposed with longer periods of non-fighting activity [pause] at average ratios between 1:2 and 1:7 in different Taekwondo styles (Tornello F 2013). These contests elicit near maximal heart rate (HR) responses (90% HR peak) and high lactate concentrations (7.0 – 12.2mmol l-1), which infer that high demands are imposed upon both aerobic and anaerobic metabolism during the bouts (Bridge, 2013). The physical activity and physiological requirements of Taekwondo competition require athletes to be competent in several aspects of fitness, including aerobic and anaerobic power, muscular strength, muscular power, flexibility, speed and agility (Bouhlel, 2006).It is therefore important that coaches and sports scientists collect objective information about their athletes. Taekwondo is one of the fastest martial arts that athletes use kicks and jumps too much, because of that plyometric and jumping training in daily training of athletes are important. Since plyometric training is popular among individuals involved in dynamic sports, and plyometric exercises such as jumping, hopping, skipping and bounding are executed with a goal to increase dynamic muscular performance and Taekwondo competitions involved in standing, startups, and changes in a sudden state of affairs, and given that proper training methods for athletes are constantly changing and updated, the research approach has led to optimization of exercises and on the other hand there is no evidence of study of the effects of plyometric exercise and blood flow restriction has been used on explosive power in Taekwondo athletes, this study was designed to answer the question whether plyometric exercises with blood flow restriction effect on Taekwondo athletes explosive power.

Material and Methods

The study included Taekwondo athletes aged under 17 years old who trained at the start of the study (September 2018) and met the inclusion criteria: the Taekwondo athletes has no acute or last month injuries, actively and regularly participates in the training process, under 17 years old, at least 2 years in the provincial league and the minimum red belt, the permission of the Taekwondo athletes involved in the study has been received, as well as the athletes agreed to participate in the study and the study includes only male participants both in intervention and the control group. The participants of the study were divided into one of two groups – experimental or control, using convenient sampling. The Group-A includes 10 participants and the Group-B includes 10 participants. After the evaluation, both groups were educated for a period of six weeks. from both groups the pre-test (Figure 1) for the variable studied, vertical jump, done.

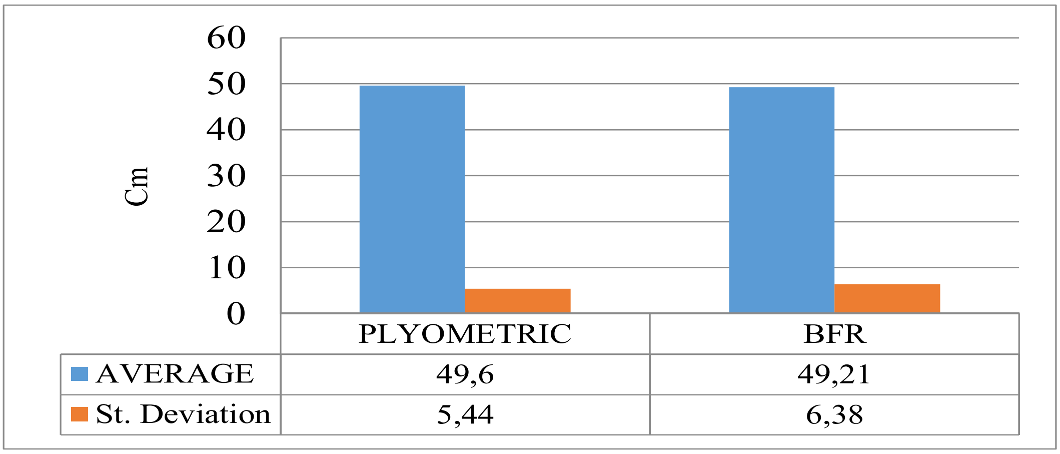

Figure 1: Shows the Pre-Test for Vertical Jump in both groups

In this test the athlete warm up for 10min and then he stood side onto the wall, keeping both feet remaining on the ground, reaches up as high as possible with one hand and marked the wall with the tips of the fingers(M1) The athlete from a static position jumped as high as possible and marks the wall with the chalk on his fingers (M2) .

The researcher measured and recorded the distance between M1 and M2. The athlete repeats the test 3 times and the researcher calculated the average of the recorded distances and used this value to assess the athlete's performance, then plyometric training program (table 1) for the two groups, including six weeks of practice, each week two sessions, and the time of each session was 45 to 60min, except that in one of the groups before exercise, vascular obstruction was performed in the thigh area, obstruction of the vessels by closing an elastic cuff around the thigh muscle in the proximal portion of both legs and a pressure of 120mmHg was used to press the cuff.

Table 1

Six-week plyometric exercises (Vaczi, 2013)

	First week	Second week	Third week	Forth Week	Fifth Week	Sixth Week
Jump ankle	3 * 10	1 * 10				
Box jump	3 * 10	1 * 10				
Vertical Jump	3 * 10	2 * 10	1 * 10			
Skater jump	3 * 7	1 * 7				
Lateral cone hops		3 * 10	2 * 10	2 * 10		
Single leg jump		3 * 5	3 * 5	3 * 5	3 * 5	3 * 5
Squat one leg jump			3 * 10	3 * 10	3 * 10	3 * 10
Standing long jump			3 * 5	3 * 5	3 * 5	3 * 5
Jump lunge			3 * 5	3 * 5	2 * 5	2 * 5
Jumping jack				3 * 5	3 * 5	3 * 5
Lateral plyometric jump				3 * 5	3 * 5	3 * 5
Froggy jump					5 * 1	5 * 1
Tuck jump					5 * 3	5* 3

The control group didn't receive any blood flow restriction and they were just allowed to do the plyometric training. From the studied, all the Taekwondo athletes completed the study (regularly exercising the research set up by the researcher, integrated into the training process; engaged in re-evaluation; did not leave the study on their own) and the functional evaluation test protocols were complete. Thus, all selected participants could be included in the results analysis. All data collected were manually entered using Microsoft Excel and analyzed using SPSS for Windows (version 19). In order to compare the groups in terms of the characteristics, pre-test and post-training changes in each group, the use of covariance analysis was used ($\alpha < 0.05$). The study was conducted in accordance with ethical principles. Confidentiality and anonymity were respected in both data collection and analysis. The study has an Ethical approval from the LASE Ethics Committee.

Results

After the completion of the 6 weeks protocol and the intervention the subjects were assessed to take the post-test values. The post-test assessment was done by using the Sargent vertical jump for measuring the explosive power of Taekwondo athletes. (Figure 2)

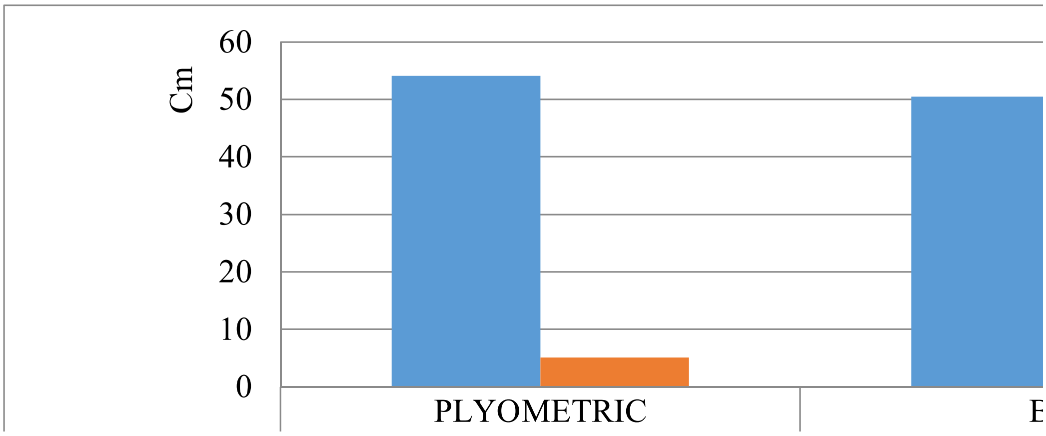

Figure 2: Shows the post-test values of Vertical jump in both groups

In the Figure 2, the subjects for intervention group were 10 Taekwondo athletes and average vertical jump was 50.46cm and the standard deviation for BFR group was 6.32. For Plyometric group the subjects were 10 Taekwondo athletes and the vertical jump was 54.13cm and the standard deviation for Plyometric group was 5.11. The subjects for control group were 10 Taekwondo athletes and the maximum jump in the plyometric group was 68cm and the minimum jump was 32.93cm and the average was 54.13cm. Comparing the results of the training process of the experimental group in pre-test and after the post-test there was not observed a statistically significant difference in vertical jump of group that they did plyometric training with blood flow restriction. In pre-test the vertical jump in BFR group was 49.21cm and standard deviation was 6.38. After six weeks of training and in post-test for BFR group the vertical jump was 50.46cm ($\alpha > 0.05$). The standard deviation was 6.32 (Table 2).

Table 2

The Statistical data related to pre-test and post-test of the scores of vertical jump of the research groups

Variable statistical indicators	Group	Pre-test		Post-test	
		Average	Standard Deviation	Average	Standard Deviation
Vertical jump (cm)	Plyometric	49.6	5.44	54.13	5.11
	BFR	49.21	6.38	50.46	6.32

Table 3 showed the results of covariance analysis on the effect of group membership on vertical jump in two groups. According to the comparing between pre-test and post-test the plyometric training with blood flow restriction does not have a significant effect on explosive power in Taekwondo athletes. Many athletes are required to concurrently develop power, speed, muscular size and strength in conjunction with other physiological qualities specific to their sport. Training for numerous adaptations is obviously time consuming and demanding on an athlete's body.

Table 3

The results of covariance analysis on the effect of group membership on vertical jump in two groups

Research variable	Variable	Degrees of Freedom	Average	F	P
Vertical Jump (centimeter)	pre-test	1	744/45	111/04	0/001
	Group membership	1	58/06	8/66	0/007
Agility (second)	pre-test	1	10/00	57/32	0/001
	Group membership	1	1/44	8/28	0/008

Comparing the results of the post-test, the results of this study showed that plyometric training with blood flow restriction does not have a significant effect on explosive power, but the records of the plyometric training group without BFR showed a significant difference in the agility and explosive power record.

Discussion

The purpose of this study was to investigate the effects of plyometric training with blood flow restriction on explosive power in Taekwondo athletes. Performance in Taekwondo may be determined by a competitor's technical, tactical, psychological, physical and physiological characteristics (Pieter, 2003). Taekwondo training is therefore structured to target these specific performance mediators. Taekwondo training involved in standing, startups, jumping and changes in a sudden state of affairs. From a physical conditioning perspective, the goal of Taekwondo training is to prepare competitors to effectively manage both the physical activity and the physiological demands of combat. This approach to conditioning requires detailed knowledge of both the physiological demands of competition and the physical capabilities of the competitors (Casolino, 2012). In championship combats, competitors perform brief periods of fighting activity [attacks] (1–5s) interposed with longer periods of non-fighting activity [pause] at average ratios between 1:2 and 1:7 in different

Taekwondo styles (Tornello, 2013,). These contests elicit near maximal heart rate (HR) responses (90% HR peak) and high lactate concentrations (7.0–12.2mmol l-1), which infer that high demands are imposed upon both aerobic and anaerobic metabolism during the bouts (Bridge, 2013). The physiological responses to blood flow restriction training are very similar to those seen in regular physical activity. The peripheral blood flow response to blood flow restriction exercise acts in a similar fashion to regular physical exercise while blood coagulation activity, oxidative stress and nerve conduction velocity do not appear to be adversely affected by low intensity blood flow restriction exercise (Loenneke, Wilson, Wilson, Pujol, & Bemben, 2011).the changes in the rate of jumping among the subjects in the common blood flow restriction group, which coincided with the plyometric training was not meaningful. Blood flow restriction training typically employs training volumes ranging from 45 to 75 repetitions of each exercise per session. Several investigations have utilized blood flow restriction combined with low-load resistance exercise to volitional fatigue (Takarada, 2000).When considering the totality of evidence; it appears that individuals new to blood flow restriction training should take care to avoid regularly training to muscular failure. In this research we used plyometric training with blood flow restriction and the volume of every exercise repetition was 30 to 45 repetitions and it can be one of the result that this volume was not sufficient when we used blood flow restriction to get significant result. Interestingly, evidence suggests that the responses to blood flow restriction exercise in athletes may be dependent on the type of athlete. Takada et al. (2012) observed that metabolic stress during blood flow restriction exercise was significantly greater in endurance runners than in sprinters. It is possible that the endurance runners, who had a higher aerobic capacity than the sprinters, are essentially more dependent on oxygen delivery during exercise, and therefore suffered a greater disturbance in energetic metabolism during blood flow restriction exercise. Furthermore, it is likely that the sprinters were physiologically more accustomed to the anaerobic environment induced by blood flow restriction, and thus were not metabolically stressed to the same degree as endurance runners (Takada, 2012). These findings should be investigated further to assess whether these acute differences in metabolic stress between different types of athletes do in fact result in dissimilar muscular adaptations. Another reason that result was not significant is related to the Limitations and Contraindications for blood flow restriction training, while blood flow restriction appears to benefit skeletal muscle adaptation, it is important to recognize the potential limitations and contraindications associated with this method. A 2006 survey of Japanese facilities that were employing blood flow restriction exercise reported the most common side effects to be subcutaneous hemorrhage and numbness, which were experienced by 13.1 and 1.3% of participants, respectively (Nakajima, 2006) and as it was reported by some of athletes in this research and maybe the numbness in their legs didn't let them to reach the best benefit of blood flow restriction.

Plyometric exercises are often focused on increasing muscle strength. Rahimi et al (2005) did a Research about the effect of 6 weeks of plyometric and power training on explosive power and muscle strength, results showed that strength and plyometric exercises lead to increased explosive power and muscle strength, but the combination of these two types of exercises in it ,is also more effective to increase muscle strength, also, the results of this study are based on the findings of Arazi et al (2011), Manimmanakorn et al (2013) all of which have a positive effect on plyometric exercises on vertical and explosive power exercises reported, but not consistent with Abe(2005) and Madaram (2011) research results that blood flow-restricted training does not improve performance in track and field male and untrained young men. Abe and Colleagues (2005) performed resistance training with vascular obstruction for two sessions per day for eight days they gave. Due to the increase in strength (6.9%) and hip circumference, the performance of the jump did not change. Interpretation of no increase in jump due to exercise program, insufficient exercise time and increased muscle strength and strength they said this. In another research, Madaram et al (2011), the effect of obstructive training they examined the vessels on the practice of jumping untrained young men. Results of improved jump performance with increased hypertrophy and muscle strength (19.6%) did not show. The researchers said that the lack of improvement in Jumping performance may not be explained by increasing power. In this research neural adaptation was not investigated but in addition to nerve adaptations such as enhancing the activation and coordination of motor units that is important factors in improving maximum output power. Tendon characteristics may also be related to the results of this study, because the tendon plays an important role in Jump activity through the storage and release of elastic energy, and this feature produces power more during dynamic movements. Neural adaptations such as increased activation and synchronization of motor units have been regarded as important factors for improving maximal power output. Previous studies on blood flow restriction training failed to show changes in motor unit activation after a period of BFRT (Kubo, 2006). One of the most important factors to consider when applying blood flow restriction is the width of the cuff. Researchers have used a range of cuff widths for both the legs (4.5 – 18.5cm) and the arms (3 – 12cm) (Fahs, 2012). Wider cuffs (13.5cm) have been shown to cause greater ratings of volume during low-load blood flow restriction, knee extension exercise when compared with narrow cuffs (5.0cm) inflated to the same restrictive pressure (Rossow, 2012) some individuals did not reach complete arterial occlusion using narrow cuffs on the legs and it can be one of the reasons that in blood flow restriction group there was not significant result in vertical jump. Loenneke et al (2012) demonstrated that systolic blood pressure was not able to explain additional variance in estimation of lower body arterial occlusion pressures and questioned the continued use of this method to determine blood flow restriction pressures.

Conclusion

The results of this study showed that plyometric training with blood flow restriction does not have a significant effect on explosive power. The responses to blood flow restriction exercise in athletes may be dependent on the type of athlete.in this study the Taekwondo athletes were under 17 years old and the training programme were new and different for them (plyometric training with blood flow restriction). The hemorrhage and numbness were reported by some of athletes in this research and maybe the numbness in their legs did not let them reach the benefit of blood flow restriction. The duration of the training period maybe was not sufficient, and the athletes had six weeks to prepare for competition, and these factors could be the cause of non-compliance. For the strength and conditioning coach looking to incorporate blood flow restriction exercise into the training program of healthy athletes, it is important to ensure that athletes are periodically exposed to heavier loads, according with the periodized training plan.

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