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Article

Effectiveness of plyometric or blood flow restriction training on technical kick force in taekwondo

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Abstract: Introduction. The aim of this study was to understand the effect of blood flow restriction (BFR) and plyometric training methods on the development of taekwondo technical kick force in active taekwondo athletes. Material and Method. 31 taekwondo athletes, aged between 15 and 18 years, voluntarily participated in the study. They were divided into the blood flow restriction, plyometric training and control groups. In addition to taekwondo training, blood flow restriction and plyometric training group were trained for 6 weeks. Technical strike force measurements were made with Herman Digital Trainer, placed on the Hasedo. The difference was examined by the paired sample t-test. Comparison of three groups was made with a use of the Friedman test. Results. Statistically significant pre- and post-test differences were found in all technical impact strength values except Tolyochagi right leg in groups participating in BFR training. The difference in the right and left foot and palding kick, the right foot tolyochagi kick, and the right-left foot dwitchagi stroke was statistically significant only in the BFR training group. Conclusions. Considering the effective development of the BFR method on technical strike force in Taekwondo athletes, it is thought that adding the BFR method to routine taekwondo training under the supervision of an expert will positively contribute to success.

Keywords: taekwondo, Herman trainer, Technical Kick Force, blood flow restriction, plyometric training.

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1. Introduction

Taekwondo is an Olympic sport discipline developed in South Korea that has gained an international character and includes attacking and offensive techniques [1]. During Taekwondo matches, the kicks which are delivered correctly to the opponent may bring about points when they are managed above a certain level of strength. In order to get points during Taekwondo matches, one should be able to display a high level of neuromuscular coordination to stop the opponent or to deliver kicks with great force to shock and imbalance the opponent [2].

Taekwondo demands a quick change in direction while keeping balance, strength, speed and body control through a high level of lower limb strength and agility to improve performance [3]. In recent years, athletes have been wearing sensor safeguards during competitions to understand the amount of force in technical kick. If the sensors on the safeguard combine with the sensors on the protective equipment that the athletes are wearing on their feet and exceed a certain stroke intensity in each weight categories, it is reflected to the athlete as points. Therefore, the need for each kick to be above a certain

force increases the importance of strength gain in taekwondo [4]. Thus, strength is one of the factors that determine athlete's performance and success in taekwondo [5].

Plyometric Training (PT), one of the training methods used for strength gain, refers to performance of stretch-shortening cycle (SSC) movements that involve a high intensity of eccentric contraction immediately after a rapid and powerful concentric contraction [6]. In plyometric training, elastic force occurs when the muscular-nervous system overcomes the resistance with a high-speed contraction. This training is a positive-negative form of strength training, aiming to use kinetic energy and force very quickly and efficiently and develop explosive jump strength [7]. High intensity training, such as quick strength exercises, causes an increase in the number of motor units involved in the movement, leading to an acceleration in the functioning of the nervous system. Plyometric exercises increase the neuromuscular structure or the concentric and eccentric action loaded on the flexible and contractile part of the muscle. The flexible structure of the muscle fiber allows the muscle to store potential energy during the eccentric phase of movement. This energy then appears as kinetic energy in the concentric contraction and also allows a fast and explosive action to take place [8, 9, 10]. When the literature is examined, it has been found that plyometric training, which is thought to have an effect on strength gain, is effective in the development of general strength [11] and Dollyo Chagi kick force in Taekwondo players [12].

In this context, another training method is defined as blood flow restriction or Kaatsu. The basic principle of these exercises is to restrict the blood circulation of the working muscle by blocking the venous flow without significantly affecting the arterial circulation. This is accomplished by wrapping a restrictive bandage or specially designed pressure belts around the limb while doing dynamic exercise. This bandage is wrapped on the top point of the extremity where the muscle to be exercised [13,14]. When this type of exercise is combined with low intensity, it promotes muscle hypertrophy and provides various performance enhancements [15, 16,17]. It has been stated in some studies that it increases muscle strength and mass and provides muscle growth stimulus [18]. This training has grown in popularity around the world for increasing performance in many athletes [19].

In the light of this information, the results of BFR and plyometric training applications where technical force development can be assessed in taekwondo athletes will contribute to the literature.

2. Materials and Methods

2.1. Participants

The research is an experimental study with pre-test and post-test control groups conducted with taekwondo athletes who hold a red belt degree and over. They train in Zirve and Toros sports clubs in the Toroslar region of Mersin province. These taekwondo athletes participate in training at least three days a week and have been doing this sport for 5 to 10 years. The "Informed Consent Form", which describes the purpose, material and method of the research prepared according to Helsinki criteria, was distributed to 31 healthy taekwondo athletes who were divided into three groups. The plyometric study group was formed as 10 athletes (aged 14.70 ±1.06) and the BFR training group as 11 athletes (aged 15.36 ±1.63). In addition, 10 athletes (aged 15.00 ±1.33) were used in the control group participating only in the Taekwondo training. Ethics committee approval was obtained from the Mersin University science ethics committee with the decision number 2017/03. Participation in the research was voluntary.

2.2. Methods

Training was applied to the groups participating in the study 3 days a week for 6 weeks. The control group has continued their normal taekwondo workouts.vPre-test/post-test measurements of 4 different taekwondo technique kick forces were taken twice for the right and left foot with Herman Trainer placed in Hasedo. The best of the

values obtained were entered into the measurement forms. The training program and method of measurement are detailed below, respectively.

2.3. Trainings Programme

I. **Plyometric Training:** The plyometric training group followed a 6-week training program of 30-minute sessions 3 times a week. The performed exercises are detailed below. In addition, the 11 movements that were made are visually shown in Figure 1.

Table 1. Weekly Plyometric Exercise Programs with the number of repetitions and sets.

Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6
Squat jump (3*5)	Split squat jump (3*10)	Zig zag hops (5*2)
Jump to box (3*10)	Tuck jump (3*10)	Single leg lateral hops (3*12)
Lateral jump to box (2*10)	Lateral box push offs (3*12)	Tuck jump (3*10)
Bounding with rings (2*12)	Bounding (3*5)	Split squat jump (3*10)
Box drill with rings (3*12)	Box drill with rings (3*12)	Box drill with rings (3*12)
Lateral hurdle jump (2*15)	Lateral hurdle jump (2*15)	Lateral hurdle jump (2*15)
Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6

1. **Squat Jump:** The position starts with legs shoulder-width apart, back straight and knees slightly bent. A subject then descends until the hip is parallel to the floor and at this point he/she leaps upward strongly. He/she bounces again 1 second after landing on two feet.
2. **Jump to box:** A subject stand with legs hip-width apart and body facing the box. He/she comes to a semi crouching position and jump into the box without waiting. After landing on the box, he/she takes a step back and descends and the movement is repeated.
3. **Lateral hurdle jumps:** Subjects' legs are hip-width apart on the side of an open box. From the semi-crouching position, he/she jumps up and sideways to the side of the box, and without waiting, jumps again to the other side.
4. **Box drill with rings:** It is made on rings that are arranged adjacent to two front and two back. Starting from the semi-crouching position, a subject double toe jumps into the first ring. Then he/she jumps to the one in front of him/her, the next one and the one behind it, respectively. The subject tries keep the time spent on the ground as short as possible.
5. **Lateral jump onto box:** A subject stands with legs hip-width apart and the side of the body facing the box. He/she comes to a semi-crouching position and jumps onto the box without waiting. After landing on the box, he/she takes a step back and descends and the movement is repeated.
6. **Bounding with rings:** A subject is descended into the rings lined up on the ground by jumping forward with a right and left foot.
7. **Tuck jump:** After standing with the legs shoulder-width apart with the knees slightly bent, a subject jumps up with all the force and pulls the knees to the chest. Immediately after landing, the other is done in the same way.
8. **Split squat jump:** Lunge position is passed. From here, a subject jumps with all force and descends to the lunge position by changing the feet in the air. The movement continues by changing the feet in this way without wasting time.
9. **Lateral box push offs:** While one foot is on the box, a subject jumps up as much as possible by using the leg which is on the ground, changes feet in the air and descends so that the other foot is on the box and the movement is repeated.
10. **Zig zag hops:** A subject goes ahead by jumping forward and sideways left and right with two feet over a straight line of about 60 centimeters.

11. **Single leg lateral hops:** A subject goes ahead by jumping forward and sideways left and right with one foot over a straight line of about 60 centimeters. After the set is finished, the subject jumps with the other foot.

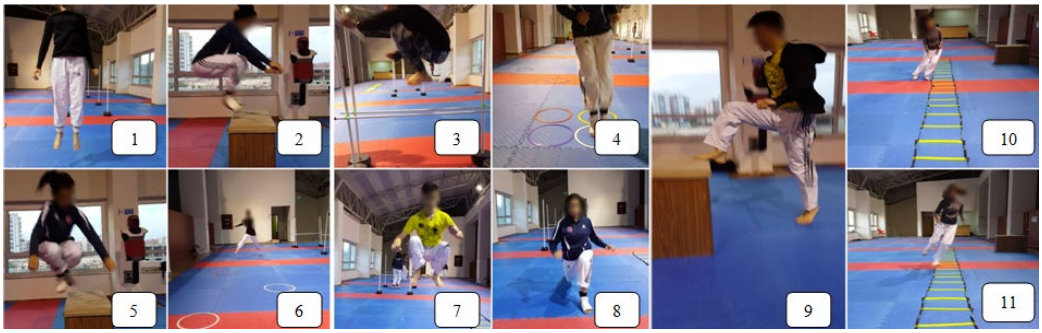

Figure 1. The 11 plyometric exercises included in the training program

II. **Blood Flow Restriction Training:** The BFR training group applied the exercises given three days a week in 3 sets of 12 repetitions for ten minutes.

The athletes apply the tires shown in Figure 2 to the top of the thighbone and after tightening the tire, apply the movements in the program in 12 repetitions and 3 sets. Explanations of the movements in workout are given below.

1. **Squat:** After standing with feet shoulder-width apart, head and shoulders facing forward, squatting is done. While squatting, the back and head maintain their upright position, and the knees do not exceed the ankle.
2. **Lunge to the front:** Stand with feet shoulder-width apart, head and shoulders facing forward. After taking a large step forward with the right foot and crouching until the knee joint is 90°, he/she stands up; the same foot is taken to the starting point. Then the same movement is repeated with the other foot. During the movement, care should be taken that the knee does not exceed the toes and the head, shoulders and back are in an upright position.
3. **Lunge to the back:** Stand with feet shoulder-width apart, head and shoulders facing forward. After taking a big step backwards with the right foot and crouching until the knee joint is 90°, he gets up; the same foot is taken to the starting point. Then the same movement is repeated with the other foot. During the movement, care should be taken that the knee does not exceed the toes and the head, shoulders and back are in an upright position.

Figure 2. Blood Flow Restriction Band and Exercises.

2.4. The Herman Digital Trainer Measurements

The device consists of a sensor and a box with a display where the values are displayed. This tool yields a unit value calculated according to the velocity of the impact force during the stroke and the vector distribution of the stroke. It specifies the equivalent of this value in terms of g value in parentheses next to the calculated unit value. With the help of this device, the acceleration that occurs during the contact of the technique with the target can be known in terms of g-force, which is approximately 9.81 meters / second-square. Thus, the unit value given by the apparatus can be followed in the pre- and post-tests, and the development of the athletes can be monitored. Figure 3 shows the graphic representation of the data of the Herman Digital Trainer measurement device. The apparatus gives the user the application of a series of strokes in the desired time, the value of each stroke, the value of the best stroke, the total value of the strokes, the average value and the total number of strokes in the display graphically and in writing [20].

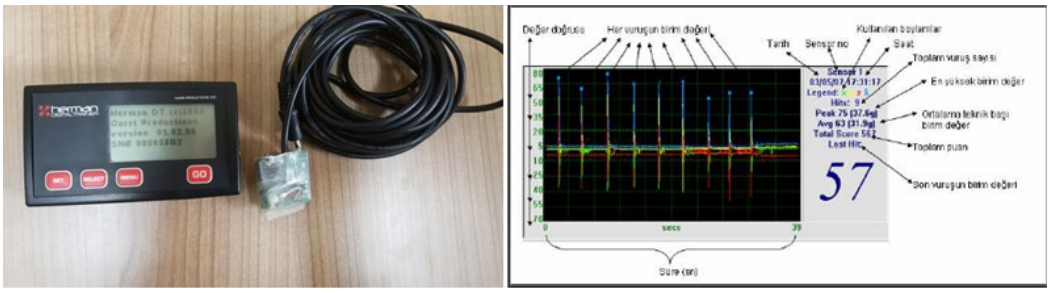

Figure 3. Herman Digital Trainer Meter and Display Screen.

The measurement of technical force development was made with the force measuring device named The Herman Digital Trainer. This device is placed on the hitting stand (Haşedo) to be hit. After the participants were given a special warm-up for 20 minutes of general and taekwondo techniques, each measuring device was introduced, and the instructions were read before the tests were applied. Participants were given two trials for device use. Participants applied palding, tolyochagi, yopchagi and dwitchagi techniques to this system twice, with the right foot and the left foot. Two values obtained as a result of the measurement by the researcher were recorded and the higher value was used for analysis.

Figure 4. Technical force measurement.

2.5. Statistical Analysis

Descriptive statistics (mean and standard deviation) of all variables were taken. The distribution of normality of the groups was examined using the Shapiro-Wilk test. After 6 weeks of plyometric and BFR training, the strength development of taekwondo technique strokes was measured by repeated measurements with the paired samples T test. Palding, tolyochagi, dwitchagi, yopchagi techniques were analyzed using the Friedman

test to determine the development between each group (difference between pre-test and post-test). 0.05 was used as the level of significance in the study.

3. Results

T test measurement values and results in pre-test–post-test repeated measurements of taekwondo technical stroke intensities taken with Herman digital trainer device of the athletes participating in the study are given in Table 2 and graphic representation is given in Figure 5. In Tables 3, 4, 5 and 6, Friedman test results of 4 different taekwondo kick values are given, respectively.

Table 2. Pre-test post-test values of technical kick strength values.

		Plyometric			Blood Flow Restriction			Control		
Techniques	Test	x̄ ±Sd	t	p	x̄ ±Sd	t	p	x̄ ±Sd	t	p
Palding right leg	pre	52.2±10.01	-0.977	.354	49.09±9.6	-4.765	**.001***	51.2±12.69	-0.28	.786
	post	56±11.59			62.64±11.39			52.1±10		
Palding left leg	pre	49.2±11.13	-1.028	.331	44.18±11.08	-7.49	**.000***	47.7±11.66	-0.332	.747
	post	53.3±11.26			60.18±9.61			46.8±12.35		
Tolyochagi right leg	pre	32.9±6.44	-2.709	**.024***	39.73±7.7	-2.025	.070	30.3±4.85	-2.298	**.047***
	post	40.5±10.78			43.82±9.14			33.1±5.72		
Tolyochagi left leg	pre	30±6.48	-4.194	**.002***	38.18±6.82	-2.868	**.017***	28.8±5.27	-0.413	.689
	post	38.6±9.07			42.45±7.83			29.6±6.36		
Dwitchagi right leg	pre	39±8.47	-1.105	.298	37.36±8.27	-3.732	**.004***	35.4±9.66	-1.597	.145
	post	43.8±6.41			45±9.6			38.3±7.47		
Dwitchagi left leg	pre	37.5±7.99	-0.831	.427	35.09±8.18	-5.954	**.000***	34.6±8.04	-0.271	.792
	post	40±5.66			42.91±8.22			34.9±7.29		
Yopchagi right leg	pre	28.9±5.09	-4.452	**.002***	31.27±5.75	-8.973	**.000***	34.9±4.93	-0.162	.875
	post	38.5±3.72			41.91±6.83			35.1±7.06		
Yopchagi left leg	pre	30.2±4.13	-3.586	**.006***	31.36±6.28	-8.343	**.000***	33.6±6.08	0	1.000
	post	37±4.29			40.73±5.97			33.6±7.04		

The increase in strength was found to be statistically significant in all technical kicks except right foot tolyochagi in athletes who were applied BFR training program. In plyometric training, a significant increase was found in the tolyochagi and yopchagi technical kicks performed with both feet. In the control group, an increase in strength was found only in the right foot tolyochagi kick.

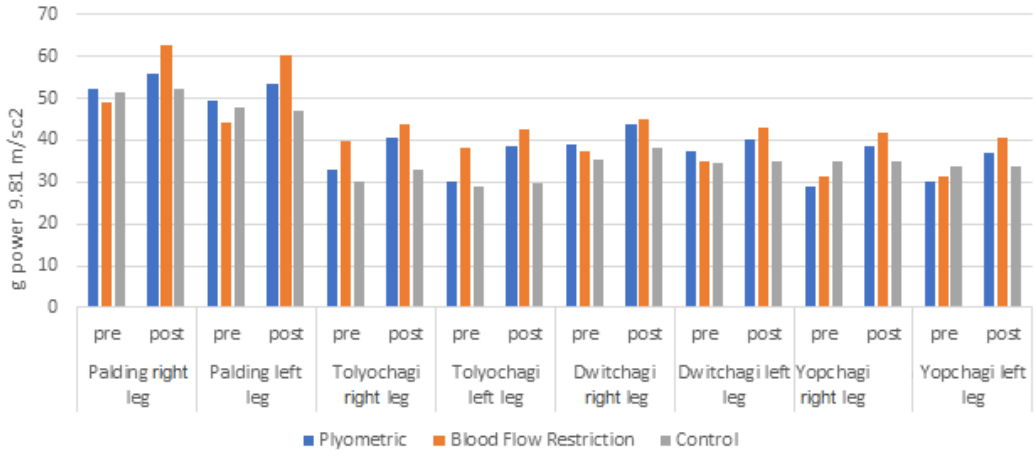

Figure 5. Pre-test post-test values of technical kick strength values.

Table 3. Palding technique pre-test post-test differences between groups Friedman analysis results.

Groups	Directions	Test	Mean rank	x^2	sd	p
Plyometric	Right	Pre-test	1.3	1.6	10.008	.206
		Post-test	1.7		11.585	
	Left	Pre-test	1.2	3.6	11.13353	0.058
		Post-test	1.8		11.26499	
BFR	Right	Pre-test	1.09	7.364	9.596	**.007***
		Post-test	1.91		11.386	
	Left	Pre-test	1	11	11.07988	**0.001***
		Post-test	2		9.6106	
Control	Right	Pre-test	1.3	1.6	12.691	.206
		Post-test	1.7		10.005	
	Left	Pre-test	1.5	0	11.66238	1
		Post-test	1.5		12.35404	

According to Table 3, the difference in the right and left foot and palding kicks was found to be statistically significant only in the BFR training group ($p < 0.005$). In the plyometric training and control groups, the training effect was not statistically significant.

Table 4. Tolyochagi technique pre-test post-test difference between groups Friedman analysis results.

Groups	Directions	Test	Mean rank	x^2	sd	p
Plyometric	Right	Pre-test	1.2	3.6	11.133	0.058
		Post-test	1.8		11.264	
	Left	Pre-test	1	10	6.48	**0.002***
		Post-test	2		9.07	
BFR	Right	Pre-test	1	11	11.079	**0.001***
		Post-test	2		9.61	
	Left	Pre-test	1.18	4.455	6.823	**0.035***
		Post-test	1.82		7.827	
Control	Right	Pre-test	1.5	0	11.662	1
		Post-test	1.5		12.354	
	Left	Pre-test	1.5	0	5.266	1
		Post-test	1.5		6.363	

While the difference was statistically significant in plyometric training in the left foot tolyochagi kick, the difference was statistically significant in both the right and left foot in the BFR training group ($p < 0.005$). No strength development was observed in the control group.

Table 5. Dwitchagi technique pre-test post-test differences between groups Friedman analysis results.

Groups	Directions	Test	Mean rank	x^2	sd	p
Plyometric	Right	Pre-test	1.4	0.4	8.472	0.527
		Post-test	1.6		6.408	
	Left	Pre-test	1.5	0	7.989	1
		Post-test	1.5		5.656	
BFR	Right	Pre-test	1.09	7.364	8.273	**.007***
		Post-test	1.91		9.602	
	Left	Pre-test	1	11	8.178	**0.001***
		Post-test	2		8.215	
Control	Right	Pre-test	1.3	1.6	9.663	.206
		Post-test	1.7		7.469	
	Left	Pre-test	1.5	0	8.044	1
		Post-test	1.5		7.294	

The difference in the right and left foot dwitchagi kick was found to be statistically significant only in the BFR training group ($p < 0.005$).

Table 6. Yopchagi technique pre-test post-test differences between groups Friedman analysis results.

Groups	Directions	Test	Mean rank	x^2	sd	p
Plyometric	Right	Pre-test	1.1	6.4	5.087	**0.011***
		Post-test	1.9		3.719	
	Left	Pre-test	1.1	6.4	4.131	**0.011***
		Post-test	1.9		4.294	
BFR	Right	Pre-test	1	11	5.746	**0.001***
		Post-test	2		6.833	
	Left	Pre-test	1	11	6.281	**0.001***
		Post-test	2		5.968	
Control	Right	Pre-test	1.45	0.111	4.931	0.739
		Post-test	1.55		7.062	
	Left	Pre-test	1.6	0.4	6.077	0.527
		Post-test	1.4		7.042	

The difference between right and left foot yopchagi kicks; both the plyometric and BFR training group were statistically significant ($p < 0.005$).

4. Discussion

The result of this study, which aims to examine the effectiveness of plyometric and blood flow restriction training on technical strike force in Taekwondo athletes, shows that the BFR method is more effective on technical kick force. According to our research results, statistically significant pre-test post-test differences were found in all technical impact strength values except Tolyochagi right leg of groups participating in BFR training. At the same time, the difference in the right and the left foot and the palding kick, the right foot tolyochagi kick, and the right-left foot dwitchagi stroke was found to be statistically significant only in the BFR training group ($p < 0.005$). BFR is characterized by high energy demand of the muscle during strength training and restricted blood flow during the period under tension. Therefore, anaerobic energy metabolism plays an important role due to the hypoxic environment to which the muscle is exposed during exercise [21]. BFR

increases the heart rate by restricting the circulation, increases the release of nitric oxide by making the heart work extra, renews the elastic blood vessels, ensures that the fast and slow twitch muscle fibers work together and blood is supplied [16].

In a study aiming to gain insight into the adaptations of muscle strength and skeletal muscle thickness after two different volumes of BFR training, it was shown that low-load blood flow restriction training causes muscle hypertrophy regardless of exercise volume [22]. Similarly, in a study examining the effect of balance development on dynamic balance of Taekwondo athletes in BFR and plyometric training, it was observed that the observed significant improvement was in favor of the BFR group [23]. In another study, Abe et al. (2006), together with BFR, reported that the combination of limb blood flow restriction with slow walking training caused muscle hypertrophy and strength gain, despite minimal exercise intensity, in their study to investigate the effects of daily physical activity [17]. Similarly, it has been reported that BFR applied together with low-intensity resistance exercise resulted in increases in muscle mass at rates comparable to the improvement in traditional strength training [24, 25]. In the study in which BFR and plyometric workouts were applied to taekwondo athletes, there was a similar increase in strength [26]. Based on this information, the data in the literature support our study.

According to the findings of our study regarding plyometric training, the difference in the left foot tolyochagi kick and the right-left foot yopchagi kick in the plyometric group and the BFR group was found to be statistically significant ($p < 0.005$). The differences observed in the right-left foot tolyochagi and yopchagi technical kicks in the plyometric group were statistically significant ($p < 0.05$).

Similarly to our study, it has been observed that the training program in which weight training and plyometric training are applied together is effective in developing explosive strength in Taekwondo players [27]. In the literature, it has been emphasized that components specific to taekwondo techniques should be taken into account during training to improve muscle strength [20]. Plyometric training is extremely effective in increasing the explosive strength, which is extremely important for the taekwondo discipline, as well as increasing the strength of skeletal muscles [28].

It is thought that fast twich fibers are strengthened with plyometric training and there is an increase in their volume [26]. It is also recommended that BFR and plyometric training, which has an important place in the training aimed at increasing strength, should be included in training programs, considering the positive effects on the strength parameters of the athletes in the taekwondo discipline.

5. Conclusions

Taekwondo is a discipline in which the forcefulness and intensity of the activity increases with each round, where anaerobic metabolism is required for energy production due to the hypoxic environment to which the muscle is exposed during exercise. The ability to generate maximum power in taekwondo in the shortest possible time is necessary to achieve a high level of sports performance. In international competitions, Taekwondo athletes use the high anaerobic power characteristics of the lower extremities effectively to achieve success. In addition to routine training methods, different techniques can be applied to achieve success, and athletes can develop versatile. Plyometric training involves training methods that produce results similar to BFR high-intensity training but can be applied with low intensity and practice, which consists of a concentric or shortening movement of the muscle and connective tissue after the eccentric contraction of the muscle and contributes to the development of strength.

According to our study, the strength development obtained in taekwondo technical strike force was found to be higher in short-term BFR training compared to plyometric training, so we recommend BFR training, so that adding the BFR method to routine taekwondo training under the supervision of an expert will contribute positively to athlete success.

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