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The Effect of Plyometric Training on Biomotoric Characteristics of 10-13 Age Taekwondo Athletes

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ORIGINAL ARTICLE

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Abstract

The aim of the study was to investigate the effect of plyometric training on the biomotoric characteristics of 10-13 years old taekwondo athletes. A total of 25 competitive taekwondo athletes aged 10-13 years, 5 males and 7 females in the control group and 7 males and 6 females in the experimental group, participated in the study. The experimental group in the study received regular piliometric training in addition to routine taekwondo training for 8 weeks, while the control group continued their routine taekwondo training program. Height and body weight measurements, BMI measurements, jump test, filamingo balance test, sit-reach-extend flexibility test, right and left hand grip test, leg strength test, back strength test, 20 meter sprint test and 20 meter shuttle run (Max.VO2) tests were applied to the athletes as pre and post tests. In our study, the descriptive statistical values of the control and experimental groups were given in tables and Paired-Samples t Test was used to compare the pre and post test values within the group and Independent-Samples t test was used to compare the pre and post test values between the groups. As a result, it was determined that plyometric training with taekwondo theme improved the physical and biomotoric characteristics of the athletes at a significant level and in this direction, it is thought that the training and competition performances of the athletes will also improve at a certain level.

Keywords: Biomotoric Characteristics, Plyometric Training, Taekwondo.

10-13 Yaş Taekwondo Sporcularına Uygulanan Pliometrik Antrenmanların Biyomotorik Özellikleri Üzerine Etkisi

Öz

Çalışmanın amacı 10-13 yaş taekwondo sporcularına uygulanan pliometrik antrenmanların biyomotorik özellikleri üzerine etkisinin incelenmesidir. Çalışmaya 10-13 yaş taekwondo sporcularından kontrol grubu 5 erkek, 7 kadın, deney grubu 7 erkek, 6 kadın toplam 25 müsabık sporcu katılmıştır. Çalışmadaki deney grubuna 8 hafta boyunca rutin taekwondo antrenmanlarına ek olarak düzenli piliometrik antrenmanlar uygulanmış, kontrol grubuna ise rutin taekwondo antrenman programlarına devam edilmiştir. Sporculara boy ve vücut ağırlığı ölçümü ile vki ölçümleri, sıçrama testi, filamingo denge testi, otur eriş -uzan esneklik testi, sağ ve sol el kavrama testi, bacak kuvveti testi, sırt kuvveti testi, 20 metre sürat testi ve 20 metre mekik koşusu (Max.VO2) testleri ön ve son test şeklinde uygulanmıştır. Çalışmamızda kontrol ve deney grubunun tanımlayıcı istatistik değerleri tablolarla belirtilmiş ve grup içi ön ve son test değerleri karşılaştırmasında Eşleştirilmiş Örneklemler t Testi ile gruplar arası ön ve son test değerleri karşılaştırmasında ise Bağımsız Gruplar İçin t Testi kullanılmıştır. Sonuç olarak, taekwondo temalı uygulanan pliometrik antrenmanların, sporcuların fiziksel ve biyomotorik özelliklerini önemli seviyede geliştirdiği tespit edilmiş ve bu doğrultuda sporcuların antrenman ve müsabaka performanslarının da belirli bir seviyede gelişim göstereceği düşünülmektedir.

Anahtar kelimeler: Biyomotorik Özellik, Pliometrik Antrenman, Taekwondo.

Introductıon

Taekwondo is a sport in which athletes use hand and foot techniques to score points against their opponent, whether for offensive or defensive purposes (İmamoğlu, 2010). As in other sports, training in taekwondo can be defined as a chain of stimuli conducted at regular intervals, creating functional and morphological adaptations in the organism (Hildbrandt, 1988). One of the different training methods, plyometric training, consists of movements where gravity is predominant and which involve body-weight exercises like jumps, single or double-leg hops, skips, and depth jumps in succession (Dolu, 1994). Plyometric training is a type of training that promotes rapid and powerful muscle contractions. This training type is of great importance especially in sports like taekwondo that require high explosive power and speed. To understand why plyometric training is important in taekwondo, one must look at the basic principles of this training type and the requirements of the sport (Foran, 2001; Baktaal, 2008).

Plyometric training is based on the principle of rapidly stretching the muscles (eccentric phase) followed by rapid contraction (concentric phase). This type of training increases the muscles' ability to store elastic energy and release it as explosive power. Plyometric training enhances athletic performance by developing the muscles' ability to contract and relax quickly, and it reduces the risk of injury. Given that taekwondo is characterized by fast kicks and punches, success in this sport largely depends on the athlete's abilities in explosive power (Chu, 1992; Parpucu, 2009), speed, agility, and coordination (Karabina & Pirselimoğlu, 2013). It is also noted that regularly performed plyometric training is effective in improving the mentioned biomotor abilities in certain muscles (Kraemer & Gomez, 2001; Yüksel, 2001; Dündar, 1998; Sevim, 1995).

Taekwondo athletes need explosive power to deliver fast and powerful kicks and punches during a match. Plyometric training increases this explosive power by promoting faster and stronger muscle contractions. Research shows that plyometric training significantly improves athletic performance by enhancing muscle strength and power (Markovic, 2007). Taekwondo is also characterized by sudden changes in direction and rapid movements. Plyometric training increases agility and coordination by ensuring that muscles contract quickly and in a coordinated manner. This allows taekwondo athletes to move faster and more effectively during a match (Aydemir et al., 2001).

Taekwondo requires dynamic strength, and kicks must be delivered with explosive power as determined by the WTF according to the legal scoring zones and weight classes (Kala, 2018; Bompa, 1998; Sevim, 1997). In taekwondo, speed is also crucial for the athlete to lift their leg to the highest speed and complete the kick in the shortest possible time during competition. The speed characteristic is important not only for executing the kicking technique but also for quickly and easily evading the

opponent's moves. One of the sub-components of speed, reaction speed, is also highly decisive for the athlete's performance in competitions (Kala, 2018).

In taekwondo, range of motion is of great importance in terms of athlete performance. That is, the flexibility and development of a taekwondo athlete's spine, hips, and legs are crucial for competition performance. Dynamic flexibility, a sub-component of flexibility, is considered very important for an athlete's success. This is because an athlete with this flexibility characteristic can perform high-level taekwondo techniques more accurately, thereby increasing their success accordingly (Ramazanoğlu, 1989; Doğan & Zorba, 1991). Therefore, plyometric training applied in taekwondo enhances the flexibility and endurance of muscles, reducing the risk of injury. Increasing muscle elasticity helps prevent injuries that can occur during sudden and high-impact movements. Research shows that plyometric training reduces the risk of injury in athletes and speeds up the rehabilitation process (Chimera et al., 2004).

In line with this information, the aim of the study was to investigate the effect of plyometric training on the biomotoric characteristics of 10-13-year-old taekwondo athletes.

Materıals and Methods

Research Model

This research employs a quantitative research method and applies an experimental research model.

Research Group

Using a simple random sampling method from taekwondo athletes in the 10-13 age category in Isparta province, the athletes participating in the study were randomly divided into two groups and two groups were formed as control group and experimental group. In the study, the control group consisted of 5 males and 7 females, totaling 12 athletes, while the experimental group consisted of 7 males and 6 females, totaling 13 competitive athletes. All individuals involved in the research procured parental consent forms. The sample size and the number of people (N) in the control and experimental groups were calculated using the G*Power 3.1.9.7 power analysis program with an effect size of d=0.2 (small).

*G*Power Analysis Minimum Sample Size and N Numbers of Groups and Table*

t tests - Means: Difference between two independent means (two groups)

Analysis: A priori: Compute required sample size

Input: Tail(s): Two

Effect size d: 0.5

α err prob: 0.05

Power (1-β err prob): 0.2

Allocation ratio N2/N1:1

Output: Noncentrality parameter δ: 1.1726039 Critical t:2. 0859634

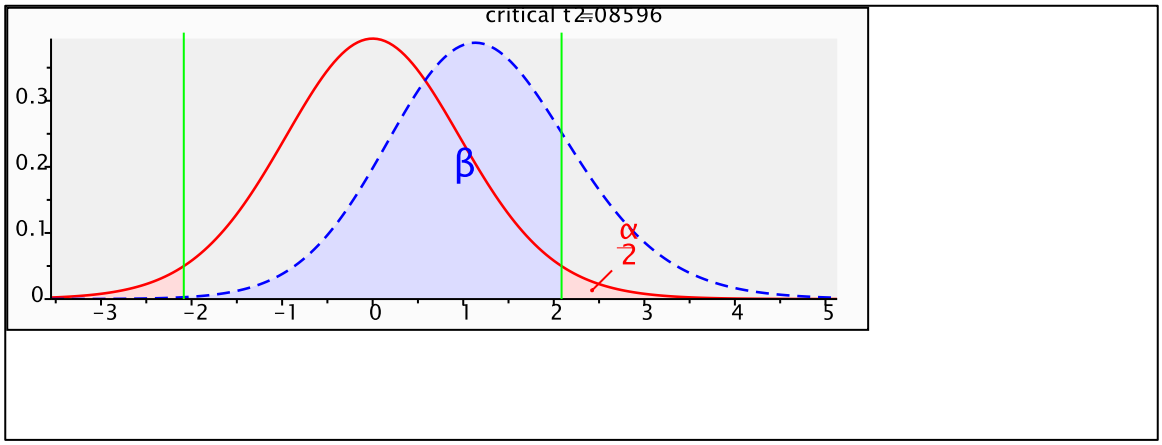
Df: 20

Sample size group 1: 11

Sample size group 2: 11

Total sample size: 22

Actual power: 0.2006271



Place and Time of Study

All tests and measurements in the study were conducted at the Indoor Sports Hall of Eğirdir Youth Services and Sports District Directorate. The experimental group in the study received regular piliometric training in addition to routine taekwondo training for 8 weeks, while the control group continued their routine taekwondo training program. In the study, pre-test measurements were taken before the athletes started their training programs and post-test measurements were taken after the 8th week of the training programs were completed.

The training programs applied to the experimental and control groups in the study were carried out by the taekwondo coach of Eğirdir Youth Services and Sports District Directorate during the out-of-school training hours of the athletes.

Taekwondo Themed 8-Week Plyometric Training Programme Applied to the Experimental Group in the Study

The taekwondo-themed plyometric training program applied by Aydemir et al. (2001) in their study titled "The Effect of Taekwondo Themed Plyometric Training on the Motoric Characteristics of 12-14 Year Old Taekwondo Athletes" in Figure 1 was used in the experimental group in our study.

Figure 1. 8-Week Taekwondo Themed Plyometric Training Programme

	Saturday	**Market**
1 and 2 Weeks	-10 minutes warm-up -Jump rope 5 minutes 12x3 -Single leg horizontal jump 12x3 -Jump to box 12x3 -Scissors palding by jumping over obstacle 12x3 -Squat jump 12x3 -Depth jumps 12x3 -Cool down for 10 minutes	-Jump rope 5 minutes 12x3 -Double foot jump to box + Double palding 12x3 -Double foot jump to box + Duchagi 12x3 -One leg jump to box 12x3 -Single leg jump to box + Tolyochagi 12x3 -Leaping duchagi 12x3 -Cool down for 10 minutes
3 and 4 Weeks	-10 minutes warm-up -Single leg horizontal jump 12x3 -One leg jump to box 12x3 +Tolyochagi 12x3 -Jump to box 12x3 + Double palding 12x3 -Jump to box Duchagi 12x3 -Cool down for 10 minutes	-Jump rope 5 minutes x3 -Single leg horizontal jump 12x3 -Single leg jump to box + Tolyochagi 12x3 -Vertical jump on the springboard + Tolyochagi 12x3 -Cool down for 10 minutes
5 and 6 Weeks	-Jump rope 5 minutes x3 -Jump to box 12x3+ Double palding 12x3 -Jump to box Duchagi 12x3 -Squat jump 12x3 -Squat jump + Jumping over obstacle 12x3 -Squat jump + Jumping over obstacle + Double palding in air 12x3 -Jumping over obstacle+Double palding in the air 12x3 -Side transition from springboard + Tolyochagi 12x3 -Cool down for 10 minutes	-10 minutes warm-up -Jump over obstacle + Double palding in the air 12x3 -Jump over obstacle + Double palding in the air + Duchagi 12x3 -Scissor palding over obstacle 12x3 -Leaping palding 12x3 -Scissor palding kick over obstacle + Backward side jump 12x3 -Vertical jump over springboard + Tolyochagi 12x3 -Cool down for 10 minutes
7 and 8 Weeks	-Jump rope 5 minutes x3 -Jump to box Duchagi 12x3 -Right left knee pull and side pass over obstacle + Yopchagi 12x3 -Scissor palding over obstacle + Backward side jump 12x3 -Jumping over obstacle + Palding in the air 12x3 -Side jump over obstacle + Scissor palding + Leaping duchagi 12x3	-Jump rope 5 minutes x3 -Squat jump + Jump over obstacle + Palding in the air 12x3 -Side pass from springboard + Tolyochagi 12x3 -Vertical jump on springboard + Tolyochagi 12x3 -Jump to box + Duchagi 12x3 -Side jump over obstacle + Scissor palding + Leaping duchagi 12x3

8-Week Taekwondo Training Programme Applied to the Control Group in the Study

The taekwondo training program depicted in Figure 2 was utilized for the control group in our study.

Figure 2. 8 Weekly Taekwondo Training Programme

	Saturday	**Market**

1 and 2 Weeks	-10 minutes warm-up -Palding-12*3 -Tolyo Chagai 12*3 -Double Palding + Tolyo Chagai 12*3 -Palding+ Tolyo Chagai+ Bandal Chagai 12*3 -10 minutes cooling	-10 minutes warm-up Palding 12*3 -Palding+ Tolyo Chagai 12*3 -Double Palding+Duitchagai -10 minutes cooling
3 and 4 Weeks	-10 minutes warm-up -Palding + Double Palding 12*3 -Front Foot Double Palding + Tolyo Chagai 12*3 -Double Tolyo+ Neryochagai 12*3 -Pushe+Duitchagi 12*3 -10 minutes cooling	-10 minutes warm-up -Double Palding 12*3 -Palding+ Double Tolyo Chagai 12*3 -Double Bandal Chagai + Double Tolyo Chagai 12*3 -Pushe + Duitchagi + Tolyo Chagai 12*3 -10 minutes cooling
5 and 6 Weeks	-10 minutes warm-up -Front Foot Double Palding + Duitchagi 12*3 -Tolyo Chagai + Bando Tolyo 12*3 -Yopchagi + Tolyo Chagai + Bandal Chagai 12*3 -10 minutes cooling	-10 minutes warm-up -Palding + Duitchagi + Tolyo Chagi 12*3 -Double Bandal Chagi + Pushe 12*3 -Bandal Chagai + Neryo Chagi + Tolyo Chagai 12*3 -Tolyo Chagai + Banda Tolyo + Tolyo Chagai 12*3 -10 minutes cooling
7 and 8 Weeks	-10 minutes warm-up -Double Palding + Duitchagai 12*3 -Front Foot Double Yopcahagi + Duitchagai 12*3 -Front Foot Double Tolyo Chagai+Banda Tolyo + Tolyo Chagai 12*3 -Mondolyo + Tolyo Chagai + Double Bandal Chagai 12*3 -10 minutes cooling	-10 minutes warm-up -Double Palding + Double Tolyo Chagai 12*3 -Double Tolyo Chagai + Banda Tolyo + Tolyo Chagai 12*3 -Double Yopchagai + Double Duitchagai + Tolyo Chagai 12*3 -Pushe + Duit Chagai + Double Tolyo Chagai 12*3 -10 minutes cooling

Materials Used in the Study

1. Jumping Stands and Rope: Cubes with a height of 40 cm are used for jumping on them and for jumping forward and sideways over them. The jump rope is adjustable according to the athlete's height.

2. Obstacles: These are jumping materials that serve as obstacles of various lengths and adjustable heights (10, 20, 30, and 40 cm).

3. Taekwondo Training Materials: Various protectors and training aids used in taekwondo strikes, such as pads, paddle gloves, guards, and helmets, were utilized. All materials and plyometric motifs used were adapted according to the exercises in the taekwondo curriculum.

Data Collection Tools Used in the Study

Warm-up Protocol Applied Before the Tests: Before the performance tests to be applied in the study, all athletes were provided with 15 minutes of light tempo warm-up running and light warm-up exercise movements in order to prevent the risk of injury during the tests. The pre and post-test performance measurement tests of all athletes after warm-up run and exercise movements were height, weight, vertical jump, flamingo balance test, sit-reach-lie flexibility test, right and left hand grip test, leg strength, back strength, 20 meter sprint tests respectively.

Height and Body Weight Measurements and BMI Calculations: The height of the athletes was measured with a height measuring device with a precision of 0.1 cm. and the results were recorded in centimeters (cm). During height measurements, athletes were asked to participate barefoot or wearing only socks. During the measurements, they were instructed to stand with their heads upright, the soles of their feet pressed flat, knees stretched, heels together, and bodies in an upright position. The body weights of the athletes were measured with a Tefal brand precision scale and the results were recorded in kilograms (kg). During measurements, athletes were asked to maintain the same position as during height measurement, and measurements were taken while wearing only a T-shirt and tracksuit bottoms. Based on the athletes' body weight and height data, the body mass index (BMI) formula (BMI: Body weight (kg)/ Height (m)^2) was calculated and recorded (Pekcan, 2008).

Vertical Jump: The athletes' jump test was conducted using the Seven Elektronik Brand SE-JP 1 Laser Vertical Jump Sensor. Before the test, the athletes were informed about the jumping movement in the test. The athletes were first asked to come to the full squat position and then they were asked to jump with their arms in the free position with the support of their arms and to make a double foot jump at the maximum level. Measurements were taken twice at 30 seconds (sec.) intervals and the highest jump was recorded in centimeters (cm).

Flamingo Balance Test: In this test, a filamingo balance test board with a length of 50 cm, a height of 4 cm and a width of 3 cm, standing on two legs with a length of 15 cm and a width of 2 cm to prevent movement, and a stopwatch were used. The athletes were asked to try to maintain their balance as much as possible for 1 minute with the balance foot on the filamingo balance board. The athlete receives support from the helper until the athlete regains balance and the test starts when the support ends. Athletes are calculated to fall from the filamingo balance board within 1 minute and the time is stopped for each fall. Total balance losses of the athletes within 1 min were calculated and recorded.

Sit-Reach-Lie Flexibility Test: Flexibility measurements of the athletes were taken with a sit-reach-extend test table. The flexibility table is 35 cm long, 45 cm wide and 32 cm high and the top surface of the table is 55 cm long, 45 cm wide. The top surface of the table is 15 cm further out than the surface on which the soles of the feet rest. Athletes were directed to maneuver a measuring ruler with their fingers within a specified region demarcated by parallel lines, each measuring 1 square centimeter. It was mandatory for athletes to maintain straight legs without bending their knees throughout the duration of the test. The evaluation procedure was repeated twice, and the highest recorded value in centimeters (cm) was documented (Tamer, 2000).

Right and Left Hand Grip Test: For the Right and Left Hand Grip Test, 57 Holtain brand hand dynamometer was adjusted according to the athlete's hand size. Participants were instructed to exert maximum force while squeezing the dynamometer, ensuring that their arm remained straight at an angle of 10-15 degrees from the shoulder without any bending at the elbow. The test was repeated twice and the highest value was recorded. (Pekel, 2007).

Leg Strength Test: The back and leg dynamometer from the Takkei brand was employed for this assessment. Athletes were directed to position themselves with bent knees, placing their feet onto the dynamometer stand, extending their arms, straightening their backs, and slightly leaning forward with their torsos. Then they were asked to pull up the dynamometer bar vertically with their hands at the highest level using their legs. The test was repeated 2 times and the best value was recorded in kilograms (kg).

Back Strength Test: Similar to the leg strength assessment, the back and leg dynamometer from the Takkei brand were utilized for this test. The athletes were asked to stand with their knees in a tense position so that only the position of their knees was different from their body position in the leg strength test. The athletes were then asked to pull up the dynamometer bar vertically as high as they could and the test was repeated 2 times and the best value was recorded in kilograms (kg).

20 Meter Speed Test: The distance of 20 meters was measured and markers were placed at the beginning and end of the distance. The Seven Elektronik Brand SE-160 Wireless Photocell Stopwatch was used for this test. Athletes were given two trials and instructed to run the specified distance at their maximum speed. The best times were recorded in seconds (sec.).

Data Analysis:

Statistical package program was used to evaluate the statistical analysis of the study. In the test results of our study, it was determined that all values showed normal distribution. In our study, age and gender frequency values and descriptive statistics values of age, height, weight, BMI and sport age of Taekwondo athletes in the control group and experimental group were presented in tables.

Paired Samples t Test was used in the comparison of weight, BMI and biomotoric measurement test values of taekwondo athletes within groups pre-test and post-test values. Independent Samples t Test was used in the comparison of weight, BMI and biomotoric measurement test values of the athletes between the pre-test and post-test values between the groups. All test results were evaluated by accepting a significance level of “0.05”.

Ethics of Research:

During the current research, the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions" was followed. This study was conducted with the Ethics Committee Approval with the decision numbered 15/251 taken at the meeting of Süleyman Demirel University Faculty of Medicine Clinical Research Ethics Committee dated 05.12.2023 and numbered 72867572-050.0 l .04-687793.

Findings

Tablo 1

Age and Gender Frequency Values of Control Group and Experimental Group Taekwondo Athletes.

Groups		**Age**	**N**
Control Group	Age	10	1
		11	7
		12	4
		Total	**12**
	Gender	Male	5
		Woman	7
		Total	**12**
Experimental Group	Age	10	2
		11	3
		12	5
		13	3
		Total	**13**
	Gender	Male	7
		Woman	6
		Total	**13**

Tablo 2

Descriptive Statistics Table of Age, Height, Weight, and BMI Values for the Control and Experimental Groups.

Groups			**N**	**Minimum**	**Maximum**	**Mean±SD**
Control Group	Age		12	10	12	11,25±,662
	Height	Pre-test	12	135	158	146,58±7,70
		Post Test	12	135	158	146,58±7,70
	Weight	Pre-test	12	27,7	58,2	38,12±9,25
		Post Test	12	28,5	58,9	39,44±9,28
	BMI	Pre-test	12	13,20	26,20	17,67±3,71
		Post Test	12	13,50	26,50	18,30±3,76
Experimental Group	Yaş		13	10	13	11,69±1,03
	Height	Pre-test	13	136	170	153,77±11,61
		Post Test	13	136	170	153,77±11,61
	Weight	Pre-test	13	27,5	70,6	44,99±13,90
		Post Test	13	27,8	72,5	46,10±14,02
	BMI	Pre-test	13	13,60	24,40	18,60±3,67
		Post Test	13	14,00	25,20	19,13±3,90

Tablo 3

Pretest and Posttest Paired Samples t-Test Results of Weight and BMI Values for the Control and Experimental Groups.

Groups	**Tests**		**Average**	**SD**	**t**	**p**
Control Group	Weight	Pre-test	38,12	9,25	-7,605	**,000***
		Post Test	39,44	9,28		
	BMI	Pre-test	17,67	3,71	-6,548	**,000***
		Post Test	18,30	3,76		
Experimental Group	Weight	Pre-test	44,99	13,90	-2,165	,051
		Post Test	46,10	14,02		
	BMI	Pre-test	18,60	3,67	-2,246	**,044***
		Post Test	19,13	3,90		

*p<0.05

In the study, when the weight and body mass index of the athletes in the control group were analyzed, it was determined that the development between the pre-test and post-test data showed statistically significant differences. When the weight data of the athletes in the experimental group were examined, it was determined that there were no significant differences between the results of the pre-test and post-test body weights. Nevertheless, it was observed that the body mass index data for athletes in the experimental group exhibited statistically significant differences between pre-test and post-test evaluations.

Tablo 4

Pre-test and Post-test Paired Samples t-Test Results for Biomotoric Tests in the Control Group.

Tests		**Average**	**SD**	**t**	**p**
Vertical Jump	Pre-test	24,79	6,77	-1,819	,096
	Post Test	25,15	6,54		
Flamingo Balance Test	Pre-test	11,67	3,52	,761	,463
	Post Test	11,42	3,20		
Sit-Lie-Reach Test	Pre-test	24,50	5,41	-,364	,723
	Post Test	24,58	5,08		
Right Hand Grip Strength	Pre-test	18,11	3,20	-1,473	,169
	Post Test	19,15	4,46		
Left Hand Grip Strength	Pre-test	16,66	3,33	-3,598	**,004***
	Post Test	17,29	3,37		
Leg Strength	Pre-test	41,50	12,08	-2,470	**,031***
	Post Test	41,87	11,93		
Back Strength	Pre-test	42,66	13,47	-1,525	,156
	Post Test	42,90	13,61		
Speed	Pre-test	3,94	,34	,333	,745
	Post Test	3,93	,26		

*p<0.05

In the study, when comparing the pre-test and post-test results of the biomotoric tests in the control group, it was found that there were no statistically significant differences in vertical jump, sprint, flamingo, back strength, right hand grip, and sit-reach tests. However, statistically significant differences were observed in the leg strength and left hand grip tests.

Tablo 5

Pretest and Posttest Paired Samples t-Test Results for Biomotoric Tests in the Experimental Group.

Tests		**Average**	**SD**	**t**	**p**
Vertical Jump	Pre-test	24,89	6,56	-2,433	**,032***
	Post Test	28,62	7,15		
Flamingo Balance Test	Pre-test	13,85	4,91	9,859	**,000***
	Post Test	9,00	3,93		
Sit-Lie-Reach Test	Pre-test	24,00	5,30	-10,773	**,000***
	Post Test	26,76	5,80		
Right Hand Grip Strength	Pre-test	21,58	6,57	-5,816	**,000***
	Post Test	23,84	6,31		
Left Hand Grip Strength	Pre-test	19,26	5,26	-15,514	**,000***
	Post Test	22,07	5,48		
Leg Strength	Pre-test	50,26	25,74	-3,824	**,002***
	Post Test	67,40	32,93		
Back Strength	Pre-test	46,73	25,34	4,798	**,000***
	Post Test	54,54	25,96		
Speed	Pre-test	4,06	,27	12,519	**,000***
	Post Test	3,11	,25		

*p<0.05

In the study, when the pre-test and post-test data of the biomotoric tests of the experimental group were compared, statistically significant differences were found in vertical jump, sprint, filamingo, leg strength, back strength, right hand grip, left hand grip, sit-reach- reach tests.

Tablo 6

Pretest Comparison of Height, Weight, and BMI Values between Control and Experimental Groups: Independent-Samples t Test Results.

Tests	**Groups**	**Average**	**SD**	**t**	**p**
Height Pre-test	Control Group	146,58	7,70	-1,806	,084
	Experimental Group	153,77	11,61		
Weight Pre-test	Control Group	38,12	9,25	-1,440	,163
	Experimental Group	44,99	13,90		
Body Mass Index Pre-test	Control Group	17,67	3,71	-,631	,535
	Experimental Group	18,60	3,67		

In the study, upon examination of the pre-test measurements of height, weight, and body mass index among participants in both the control and experimental groups, it was concluded that there were no statistically significant variances observed between the two groups.

Tablo 7

Independent-Samples t Test Results for Posttest Comparison of Height, Weight, and BMI Values between Control and Experimental Groups

Tests	Groups	Average	SD	t	p
Height Post Test	Control Group	146,58	7,70	-1,806	,084
	Experimental Group	153,77	11,61		
Weight Post Test	Control Group	39,44	9,28	-1,387	,179
	Experimental Group	46,10	14,02		
Body Mass Index Post Test	Control Group	18,30	3,76	-,541	,594
	Experimental Group	19,13	3,90		

In the study, upon analyzing the post-test measurements of height, weight, and body mass index among participants in both the control and experimental groups, it was established that there were no statistically significant variances observed between the two groups.

Tablo 8

Independent-Samples t Test Results for Pre-Test Comparison of Biomotoric Tests between Control and Experimental Groups

Tests	Groups	Average	SD	t	p
Vertical Jump Pre-test	Control Group	24,79	6,77	-,038	,970
	Experimental Group	24,89	6,56		
Flamingo Balance Test Pre-test	Control Group	11,67	3,52	-1,265	,219
	Experimental Group	13,85	4,91		
Sit-Lie-Reach Test Pre-test	Control Group	24,50	5,41	,233	,818
	Experimental Group	24,00	5,30		
Right Hand Grip Strength Pre-test	Control Group	18,11	3,20	-1,653	,112
	Experimental Group	21,58	6,57		
Left Hand Grip Strength Pre-test	Control Group	16,66	3,33	-1,462	,157
	Experimental Group	19,26	5,26		
Leg Strength Pre-test	Control Group	41,50	12,08	-1,074	,294
	Experimental Group	50,26	25,74		
Back Strength Pre-test	Control Group	42,66	13,47	-,494	,626
	Experimental Group	46,73	25,34		
Speed Pre-test	Control Group	3,94	,34	-,925	,365
	Experimental Group	4,06	,27		

In the study, when the pre-test data of the biomotoric tests of the control and experimental groups were compared, it was determined that there were no statistically significant differences in vertical jump, sprint, filamingo, leg strength, back strength, right hand grip, left hand grip, sit-reach-reach tests.

Tablo 9

Independent-Samples t Test Results for Posttest Comparison of Biomotoric Tests between Control and Experimental Groups

Tests	Groups	Average	SD	t	p
Vertical Jump Pre-test	Control Group	25,15	6,54	-1,260	,220
	Experimental Group	28,62	7,15		
Flamingo Balance Test Pre-test	Control Group	11,42	3,20	1,675	,108
	Experimental Group	9,00	3,93		
Sit-Lie-Reach Test Pre-test	Control Group	24,58	5,08	-,997	,329
	Experimental Group	26,76	5,80		
Right Hand Grip Strength Pre-test	Control Group	19,15	4,46	-2,127	**,044***
	Experimental Group	23,84	6,31		
Left Hand Grip Strength Pre-test	Control Group	17,29	3,37	-2,598	**,016***
	Experimental Group	22,07	5,48		
Leg Strength Pre-test	Control Group	41,87	11,93	-2,533	**,019***
	Experimental Group	67,40	32,93		
Back Strength Pre-test	Control Group	42,90	13,61	-1,386	,179
	Experimental Group	54,54	25,96		
Speed Pre-test	Control Group	3,93	,26	7,836	**,000***
	Experimental Group	3,11	,25		

*p<0.05

In the study, when the post-test data of the biomotoric tests of the control and experimental groups were compared, it was found that there were no statistically significant differences in vertical jump, filamingo, back strength, sit-lie-reach tests. However, when the post-test data of the biomotoric tests of the control and experimental groups were compared, statistically significant differences were found in sprint, leg strength, right hand grip and left hand grip tests.

Discussion

In our study, the effects of plyometric training practices on the height, weight, body mass index (BMI) and biomotor characteristics of vertical jump, sprint, balance, back and leg strength, right and left hand grip and flexibility of the control group and experimental group consisting of taekwondo athletes aged 10-13 years. In our study, height, weight, BMI and biomotor characteristics of the athletes were measured in two stages as pre-test and post-test.

In our study, it is observed that the pre-test average weight of the control (38.12±9.25) and experimental (44.99±13.90) groups of taekwondo athletes increased in comparison to their post-test average weight of the control (39.44±9.28) and experimental (46.10±14.02) groups. Similarly, an increase is seen in the Body Mass Index (BMI) values, with the pre-test BMI averages of the control (17.67±3.71) and experimental (18.60±3.67) groups showing an increase in the post-test BMI values of the control (18.30±3.76) and experimental (19.13±3.90) groups. The increase in BMI values in both groups is attributed to the athletes' height remaining constant while their weight increased. The difference in the average weight between the control and experimental groups is thought to be due to

the experimental group following a more intense training program, which included plyometric training in addition to their routine taekwondo training, compared to the control group.

In the literature, a study by Şahin et al. (2011) also compared the weight values of seven- and eight-year-old taekwondo athletes and found statistically significant differences in weight values, which also led to statistically significant differences in BMI values. It was determined that the findings of our study, where the height of the athletes remained constant but the increase in weight led to an increase in BMI values, are similar to the findings of this study.

Among athletes aged 10-12, where biomotor development and performance improvement are continuous, one of the indicators of explosiveness is vertical jump ability. When examining the findings of the vertical jump ability of the athletes in our study, it is seen that the pre-test (24.89±6.56) and post-test (28.62±7.15) averages of the experimental group show that the applied plyometric training significantly improved the vertical jump ability of the experimental group. However, the pre-test (24.79±6.77) and post-test (25.15±6.54) average vertical jump values of the control group showed a very low improvement. When the pre-test and post-test vertical jump averages of these two groups are compared, it is observed that there is no significant difference in vertical jump ability between the two groups.

In his study investigating the effect of plyometric training on the vertical jump of taekwondo athletes, Gülen (2021) divided the athletes into two groups: control and experimental. The experimental group was given additional plyometric training programs, unlike the control group. Significant differences were observed in the pre-test and post-test vertical jump averages of both groups; however, when comparing the pre-test and post-test data between the two groups, no significant differences were found in the pre-test vertical jump data, while significant differences were detected in the post-test vertical jump data. Based on the pre-test and post-test vertical jump data of the experimental group in our study and the vertical jump data from Gülen's (2021) study, we can say that plyometric training programs applied in taekwondo have positive effects on the vertical jump biomotor characteristics of athletes. Çavdar (2006) stated that plyometric training methods, arranged according to age groups, gender, and the athlete's sports background, can be used as a fundamental exercise program to improve athletes' balance and jump performance. There are many studies in the literature on this topic in various sports branches (Cheng et al., 2003; Öztin et al., 2003; Orhan et al., 2008; Öztürk, 2019; Markovic, 2007; Pancar et al., 2018).

In taekwondo, the balance characteristic during training or competitions, whether standing on one foot or both, is considered crucial for the athlete's performance, especially when executing kicks for defense or attack specific to the sport. In this context, when examining the findings of the flamingo balance test measurements in our study, there is no significant improvement in the pre-test (11.67±3.52) and post-test (11.42±3.20) averages of the control group. However, there is a significant

improvement in the pre-test (13.85±4.91) and post-test (9.00±3.93) averages of the experimental group. When the average values of the flamingo balance test of these two groups are examined, no statistically significant difference is observed between the two groups.

Kaplan et al. (2020) examined the effects of plyometric training on balance performance in adolescent taekwondo athletes and found statistically significant differences in the pre-test and post-test balance measurements of the control and experimental groups. However, when comparing the pre-test and post-test balance measurement findings of these two groups, no statistically significant differences were found. The balance performance results of our study are similar to those in this study from the literature. Balance, one of the important determining characteristics for performance in sports, is also a widely studied topic in different sports disciplines (Tekin, 2016; Patti et al., 2018; Şimşek, 2019; Sevinc and Şıktar, 2016).

The flexibility characteristic in athletes varies according to multiple factors such as the athlete's joint structure, muscle mass, flexibility of joint capsules or collagen tissues, the size or smoothness of the articulating bony surfaces, intra- and intermuscular coordination, age, gender, psychological state, environmental conditions, training level, fatigue, and warm-up (Ziyagil et al., 1994; Baltacı et al., 2003). In light of this information, when examining the average flexibility characteristics of the athletes in our study, no improvement is observed in the pre-test (24.50±5.41) and post-test (24.58±5.08) measurements of the control group. However, an improvement is seen in the pre-test (24.00±5.30) and post-test (26.76±5.80) flexibility measurement averages of the experimental group. Nonetheless, this improvement in the experimental group does not show a significant difference when compared to the average flexibility characteristics of the athletes in the control group.

According to the information provided by Ziyagil et al. (1994) and Baltacı et al. (2003), the lack of variability between the flexibility measurement averages of the control and experimental groups in our study may be an expected result. When examining the effect of plyometric training on the flexibility characteristics of athletes in the literature, many studies (Öner, 2021; Radwan et al., 2021; Neves da Silva et al., 2017; Sáez de Villarreal et al., 2021; Faigenbaum et al., 2007; Almeida et al., 2021; Racil et al., 2020) are found to be similar to the information provided by Ziyagil et al. (1994) and Baltacı et al. (2003) and the findings of our study.

When examining the pre-test and post-test findings of the right and left grip strength of the control and experimental groups in our study, no significant improvement is observed in the control group's right-hand grip strength pre-test (18.11±3.20) and post-test (19.15±4.46) average values, while an improvement is detected in the left-hand grip strength pre-test (16.66±3.33) and post-test (17.29±3.37) average values. In the findings of the experimental group, significant improvement is observed in the right-hand pre-test (21.58±6.57) and post-test (23.84±6.31) and the left-hand grip

strength pre-test (19.26±5.26) and post-test (22.07±5.48) average values. When comparing the pre-test right (18.11±3.20) and left (16.66±3.33) hand grip strength average values of the control group with the experimental group's pre-test right (21.58±6.57) and left (19.26±5.26) hand grip strength average values, no significant differences are found. However, significant differences are found when comparing the control group's post-test right (19.15±4.46) and left (17.29±3.37) hand grip strength average values with the experimental group's post-test right (23.84±6.31) and left (22.07±5.48) hand grip strength average values.

Genç and Dağlıoğlu (2021) divided young taekwondo athletes into a control group and an experimental group and applied an 8-week plyometric training program to the experimental group. In their study, no statistically significant differences are found in the right and left hand grip strength measurements of the control group athletes, whereas significant differences are found in the right and left hand grip strength measurements of the experimental group athletes. The results of Genç and Dağlıoğlu's study are similar to the results of our study. The reason for the development in the average grip strength characteristics in both Genç and Dağlıoğlu's study and our study is thought to be due to the various hand and arm exercises used in taekwondo sport and training, rather than the 8-week plyometric training.

In our study, significant differences were found in the leg strength test of the control group, which continued with taekwondo training for eight weeks, between the pre-test (41.50±12.08) and post-test (41.87±11.93) values. However, no statistically significant differences were found in the back strength pre-test (42.66±13.47) and post-test (42.90±13.61) values. In contrast, the experimental group, which also implemented a plyometric training program in addition to taekwondo training, showed significant differences in both leg strength pre-test (50.26±25.74) and post-test (67.40±32.93) values, as well as in back strength pre-test (46.73±25.34) and post-test (54.54±25.96) values. When comparing the control group’s pre-test (41.50±12.08) and the experimental group’s pre-test (50.26±25.74) leg strength averages, no significant difference was observed between the two groups. However, significant differences were found in the post-test leg strength values, with the control group’s post-test (41.87±11.93) and the experimental group’s post-test (67.40±32.93) averages. In the comparison of the control group’s post-test (42.90±13.61) and the experimental group’s post-test (54.54±25.96) back strength values, no significant difference was detected. According to the findings on leg and back strength averages in our study, it is evident that taekwondo training, which primarily utilizes the legs, is effective in developing athletes' leg strength. Additionally, it has been observed that the plyometric training applied alongside taekwondo training leads to further improvement in the athletes' leg strength. While the plyometric training also contributes to the development of athletes' back strength, similar to leg strength, it does not have a significant effect on the development of back strength beyond the taekwondo training, as seen in the findings of our study.

In a meta-analysis study in the literature, it was found that creating combinations from different plyometric training programs suitable for the sport, rather than preferring a single method in the training programs applied by athletes, is more effective in maximizing athletes' power performance (Villarreal et al., 2009). In another study, Reyment and colleagues (2006) determined that plyometric training conducted twice a week for four weeks significantly improved the athletes' leg strength; however, they indicated that four weeks of plyometric training was insufficient for power performance and that a longer duration was necessary. Similarly, Wilson and colleagues (1996) reported that eight weeks of plyometric training applied to 41 trained male athletes resulted in a statistically significant increase in the athletes' lower extremity force production values. These studies in the literature support the findings of our study regarding leg and back strength. Additionally, there are many studies in the literature showing that plyometric training applied in various sports significantly increases athletes' leg and back strength (Topuz, 2008; Ağılönü and Kıratlı, 2015; Dallas et al., 2020; Yarayan and Müniroğlu, 2020).

The speed characteristics of athletes in certain sports are expressed as important factors determining performance (Gil et al., 2007). In taekwondo, the speed characteristics of athletes are also considered a decisive feature of competition performance. In our study, there was no observed improvement in the speed characteristic averages of the control group athletes between the pre-test (3.94±0.34) and post-test (3.93±0.26). However, significant differences were found in the speed characteristic averages of the experimental group athletes applying plyometric training between the pre-test (4.06±0.27) and post-test (3.11±0.25). When comparing the control group's pre-test speed characteristic averages (3.94±0.34) with the experimental group's pre-test averages (4.06±0.27), no difference was observed. In contrast, significant differences were identified between the control group's post-test speed characteristic averages (3.93±0.26) and the experimental group's post-test averages (3.11±0.25).

When examining the findings of the study by Sarısoy and Sefa (2022) titled ‘The Effect of Eight Weeks of Structured Plyometric Training on Selected Physical and Physiological Parameters in Competitive Female Taekwondo Athletes,’ it was found that the plyometric training applied did not result in statistically significant improvements in speed characteristics between the control and experimental groups in the pre-test and post-test results. Additionally, no development was observed in the comparison of the speed characteristics between these two groups in the study. The reason for the statistically different results in speed characteristics compared to our study may be attributed to the intensity and frequency of the plyometric training applied in our study. In line with these results, we can say that the plyometric training program we implemented in our study is effective in the development of speed characteristics in taekwondo athletes.

In another study in the literature, Ağılönü and Kıratlı (2015) also applied an eight-week plyometric training program; however, unlike our study, this research was conducted on female handball athletes. When examining the findings related to the speed characteristics of the female handball players in the study, it was found that there was no improvement in the pre-test and post-test speed characteristics of the control group, while the experimental group showed improvements in their speed characteristics from pre-test to post-test. This study demonstrates that plyometric training is an effective training method for developing the speed motor characteristics of athletes, similar to our findings. There are also many other studies in the literature on this topic (Villarreal et al., 2009; Orhan et al., 2008).

In conclusion; taekwkondo sport is a type of sport that includes jumping, leaping, single and double foot hopping movements. In order to increase the performance of the athlete with the development of these movements, it is thought that planning and implementing plyometric training, which is an important type of training in order to produce power in the muscle contraction / stretching cycle, with movements specific to taekwondo sport will be important in terms of improving the performance of athletes. With these thoughts, it has been determined that plyometric training with taekwondo theme causes a significant improvement in the physical and biomotoric characteristics of the athletes and in this direction, it is thought that the training and competition performances of the athletes will also improve at a certain level.

Ethics Committee Permission Information

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Both authors contributed equally at all stages of the research.

Conflict Statement

The authors do not declare any conflicts with the research.

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