ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Research Article *Araştırma Makalesi* DOI: 10.62425/rses.1645763

Effects of Different Plyometric Training on Some Biomotor and Taekwondo Technical Performance in Taekwondo Athletes

Farkli Pliometrik Antrenmanların Taekwondo Sporcularında Bazı Biyomotor ve Taekwondo Teknik Performansına Etkisi

Murat KUL[1]
[1]Bayburt University, Faculty of Sports Sciences, Department of Coaching Education, Bayburt, Türkiye

Burakhan AYDEMİR[2]
[2]Karadeniz Technical University, Department of Physical Education, Trabzon, Türkiye

ABSTRACT

The aim of this study is to examine the effects of different plyometric training methods on the biomotor and taekwondo technical performance of 14-16-year-old taekwondo athletes. The study utilized two different training methods: plyometric exercises on sand and plyometric exercises on taekwondo mats, with a control group performing only regular taekwondo training. The study included 66 athletes, all with at least 5 years of taekwondo experience, from Trabzon, Turkey, in 2024. Participants were divided into two experimental groups: Group 1, performing plyometric exercises on sand, and Group 2, performing plyometric exercises on taekwondo mats. After an 8-week training program, biomotor and technical performance tests were applied to all groups for comparison. The data were tested for normal distribution using the Kolmogorov-Smirnov test, and since the data did not show normal distribution, non-parametric tests were used for analysis. Wilcoxon tests were applied for within-group comparisons, while Kruskal-Wallis tests were used for between-group comparisons. In cases where significant differences were found, Post hoc multiple comparison tests with Bonferroni correction were used to identify which groups showed the differences. The results showed that all groups demonstrated significant improvements in biomotor and technical performance parameters after the training programs. Group 1, the sand-based plyometric training group, showed more pronounced improvements in speed, agility, jump, balance, and technical performance parameters. The findings suggest that sand-based plyometric training has a significant impact on sports requiring speed, power, endurance, and technical skills, such as taekwondo.

Keywords: Plyometric, performance, training, taekwondo

ÖZ

Bu çalışmanın amacı, farklı pliyometrik antrenman yöntemlerinin 14-16 yaşlarındaki tekvando sporcularının biyomotor ve tekvando teknik performansına etkilerini incelemektir. Çalışmada, kumda pliyometrik egzersizler ve tekvando minderi üzerinde pliyometrik egzersizler olmak üzere iki farklı antrenman yöntemi kullanılmış ve kontrol grubu sadece düzenli tekvando antrenmanı yapmıştır. Çalışmaya, 2024 yılında Türkiye'nin Trabzon kentinden en az 5 yıllık tekvando deneyimine sahip 66 sporcu dahil edilmiştir. Katılımcılar iki deney grubuna ayrılmıştır: Kumda pliyometrik egzersizler yapan Grup 1 ve tekvando minderi üzerinde pliyometrik egzersizler yapan Grup 2 8 haftalık bir antrenman programının ardından, tüm gruplara biyomotor ve teknik performans testleri uygulanmıştır. Veriler, Kolmogorov-Smirnov testi kullanılarak normal dağılıma göre test edilmiş ve normal dağılım göstermediğinden, analiz için parametrik olmayan testler kullanılmıştır. Grup içi karşılaştırmalar için Wilcoxon testleri, gruplar arası karşılaştırmalar için ise Kruskal-Wallis testleri kullanılmıştır. Anlamlı farkların bulunduğu durumlarda, hangi grupların fark gösterdiğini belirlemek amacıyla Bonferroni düzeltmeli Posthoc çoklu karşılaştırma testleri yapılmıştır. Sonuçlar, tüm grupların antrenman programlarından sonra biyomotor ve teknik performans parametrelerinde anlamlı iyileşmeler gösterdiğini ortaya koymuştur. Kum tabanlı pliyometrik antrenman grubu olan 1. grup, hız, çeviklik, sıçrama, denge ve teknik performans parametrelerinde daha belirgin iyileşmeler göstermiştir.

Anahtar Kelimeler: Pliometrik, performans, antrenman, taekwondo

Geliş Tarihi/Received 24.02.2025
Kabul Tarihi/Accepted 26.06.2025
Yayın Tarihi/Publication Date 25.09.2025

Sorumlu Yazar/Corresponding author: Burakhan AYDEMİR
E-mail: burakhanaydemir@ktu.edu.tr
Cite this article: Kul, M., & Aydemir, B. (2025). Effects of different plyometric training on some biomotor and taekwondo technical performance in taekwondo athletes. *Research in Sport Education and Sciences, 27*(3), 184-199.

Introduction

One of the training methods that develops some biomotor skills of athletes such as speed, strength, and explosive power and aim to take performance to the highest levels is plyometric training (Ojeda et al., 2023). The main purpose of the training is to develop the fastest and most explosive muscle group along with the tension-contraction cycle of the muscles and to take the athlete's current performance status to the highest point. Plyometric training is one of the most widely used methods for performance parameters such as balance, speed, and explosive power, which are fundamentally important for all sports branches (Apollaro et al., 2024; Aydemir et al., 2021; Ouergui et al., 2022). These trainings are used as a more specific training model, especially in branches that stand out as combat sports (Aydemir et al., 2021; Ölmez et al., 2022). Taekwondo, one of these branches, is a sport where high efficiency is expected from plyometric training, especially due to the complicated use of parameters such as balance, speed, explosive power and agility (Pardos et al., 2021).

Taekwondo is a sport that requires high concentration, especially in which the lower extremities are widely used, fast and explosive techniques are used, sudden changes of location are made, attack and counter-attack strategies are included, jumps and turns occur frequently (Oliver et al., 2024). The effect of plyometric training stands out to reach the best level of these features and to increase the technical quality of the athletes.

Age periods have a critical threshold in the physical and technical development of young athletes, and it is known that the adolescence period of athletes in the 14-16 age group is a phase in which the neuromuscular system begins to gain strength, motor skills develop, and the maturation process accelerates (Malina et al., 2015). Correct and regular training applied to athletes at this age contributes to the development of athletes in the long term (Mujika et al., 2018). In the light of the information obtained from literature, it is thought that the positive developments that plyometric training creates in the neuromuscular system during the tension and contraction cycle will also contribute to the development system of athletes.Analyzing the effects of plyometric training provides an important opportunity to optimize athlete development and assess these results. (Silva et al., 2019; Stojanovic et al., 2017).

Plyometric training includes different types of work including jumps, acceleration and deceleration, and throwing, and contributes to the development of performance parameters such as balance, strength, agility, and speed (Aydemir et al., 2021). Each type of work contributes to the development of different muscle groups (Chen et al., 20239). While work including jumps, throws, and bounces contributes to the development of explosive power, work involving changes of direction contributes to the development of parameters such as agility and speed (Fiorilli et al., 2020). In addition, while the exercises performed one after the other in the studies increase balance performance, lengthening and shortening muscle groups also contribute positively to flexibility performance (Aydemir et al., 2021).

Since taekwondo athletes compete in an area where their technical skills are particularly high, their training methods must also be in the same form (Ölmez et al. 2022). With training programs organized in this form, it is aimed to develop the athlete's technical capacity and technical skills by improving their performances such as balance, speed, explosive power, and agility. In this direction, a taekwondo athlete's technique must include biomotor skills such as reaching the target quickly, powerfully, and in a balanced way, sudden attacks and changes of direction consisting of counterattacks, ensuring coordination in successive strikes and positions, and having a high level of short-term and medium-term endurance performance (Moran et al., 2021). In this direction, plyometric training is one of the training methods that contribute to the development of the specified parameters (Ramirez et al., 2020).

In addition, there are studies showing that doing exercises in different areas contributes to both the mental and physical development of athletes (Lemay et al., 2019). One of these areas is exercises done on sand. It is observed that with the resistance created in exercises done on sand, there are improvements in performance parameters such as endurance, speed, power production, balance and coordination of athletes (Singh et al., 2022). As a result of this information, it is thought that plyometric training can also make positive contributions to the performance of athletes. In this direction, this study aims to examine the effects of different types of plyometric training on the performance of taekwondo athletes in the 14-16 age group.

Methods

In the study, experimental design was used as a quantitative research method (Şimşek, 2012). In the study, participants are determined by random assignment method and while the experimental group is subjected to an application, the control group is not applied (Mertens, 2015).

Ethical Approval

Ethics committee approval for this study was received from Bayburt University (Date: November 4, 2024, Decision No: E-15604681-100-236987). Verbal consent was obtained from all the participants.

Participants

The participants in the study consist of active licensed taekwondo athletes residing in Trabzon province in 2024. The athletes were selected from athletes who had at least 5 years of taekwondo experience and had the criteria to compete in national competitions (at least red and black belt). When selecting the athletes, the age group of athletes with the highest number in the region was preferred. When the participants were examined according to gender factors, it consisted of 33 male and 33 female athletes. The participants in the study were randomly divided into two groups and the first measurements were performed before the study. These groups were determined as the control group (plyometric training group performed on the taekwondo ground) and the experimental group (plyometric training group performed on the sand). In this context, the distributions of the experimental group and control group determined are given in Table 1. Experimental group 1 participants consisted of 11 male and 11 female athletes, experimental group 2 participants consisted of 11 male and 11 female athletes, and control group participants consisted of 11 male and 11 female athletes. The experimental group participants did taekwondo training 3 days a week and did plyometric exercises on sand for 3 days. The experimental group 2 participants did taekwondo training 3 days a week and did plyometric exercises on the taekwondo mat for 3 days. The control group participants did taekwondo training 6 days a week. The participants continued their work for 8 weeks. All participants were given tests before and after the training plan.

Table 1.
Participants

Groups	Number of Athletes	
Experimental Group 1 (Sand Plyometric Training Group)	22	Total 66
Experimental Group 2 (Plyometric Training Group on the Mat)	22	
Control Group (Taekwondo Training Group)	22	

Data Collection Tools

20-Meter Speed Test: A Microgate Witty brand photocell device with a sensitivity of 0.01 seconds was set up on a flat 20-meter surface. At this stage, the participants first warmed up and made a few attempts. At the beginning of the measurement, an area was determined for them to start from one meter behind the photocell and when the participants felt ready, they ran in the 20-meter area. Then, after a full rest, their 2nd repetition was made. Their best times were considered and recorded in seconds (Rinaldo et al., 2020).

Pro Agility (5-10-5) Test: Known as an effective change of direction test, the pro agility test is also referred to as the 5-10-5 shuttle. The athlete is ready in the middle of the 10-meter designated running track (in a 5-meter area). The athlete, who starts the test at any time, makes a sideways run to the mark located 5 meters to the right. Then, the 2nd run is made to the mark located on the other side of the starting point. Finally, the test is completed by running to the starting point. The test was repeated twice with a 5-minute interval and the result was recorded in seconds (Harman et al., 2000).

Flexibility Test (Sit-Reach Flexibility Test): The Sit-Reach Flexibility Test (Sit and Reach Test) is a widely used test to assess flexibility levels. This test is specifically used to measure the flexibility of the hamstring muscles and the lumbar region. It can also be used to assess overall body flexibility. The aim of the test is to have the participant extend their legs straight and reach as far forward as possible without using their body weight (Behnia & Parnian, 2020).

Vertical Jump Test (CMJ): In the tests conducted with the My Jump application, participants waited on a flat surface with a camera recording at 240 Hz placed in front of them. Before the test, athletes prepared for the test by warming up and practicing. The aim of the test was for athletes to jump to the highest point they could by bending their knees 30 degrees and to fall to the same place from this peak point. The test was conducted twice with a 5-minute interval and each athlete's best

jump degree was recorded in cm (Balsalobre-Fernández et al., 2015).

Balance Test (Stork balance): The stork balance test was applied to measure the balance performance of the participants. The participants were ready on a flat surface. When they were ready, the other leg was bent so that the supporting leg was fixed on the ground and the foot plate was placed on the knee of the supporting leg and the hands were kept fixed on the waist. The athlete could stand on tiptoe whenever he wanted, and the test started during this time. The separation of the hands from the waist, the sole of the foot touching the ground, and the separation of the leg fixed on the knee were determined as the elements that ended the test. The test ended and recorded in seconds when the athlete performed one of the situations that ended the test (Negra et al., 2017).

Rast Test (Anaerobic Based Test): The Rast test, which has been tested for validity and reliability, was used to determine features such as anaerobic power and fatigue index. A two-door photocell was set up on a 35-meter flat running surface where the athletes would run and the distances they ran would be measured. The test was carried out over 6 runs. The test started when the athlete was ready, and the time stopped when he ran the distance. The 1st run is recorded in this way. The athlete rests for 10 seconds and the last 5 seconds are given a command, the countdown begins, and the run begins with the signal. The 2nd run time of the athlete who arrives at the starting point is recorded. In this way, the time of each run repeated 6 times is recorded (Zagatto et al., 2009).

Aerobic Test (Yoyo test): The Yoyo test is a fitness test applied to determine the aerobic power performance of the participants. The participants run in a determined 20-meter area with increasing speed with continuously increasing signals. Since these signals are constantly increasing, the participants are expected to increase their running pace during this process. The participants must enter the determined area with each signal. The tests of the participants who cannot reach the running area with 2 signals are terminated. The rest periods of the participants are shortened during this process. The participants are expected to recover quickly and reach the determined area with the next signal. The participants are evaluated based on their last running level, speed and distance (Bangsbo et al., 2008; Karakoç et al., 2012).

Technical Performance (Taekwondo Electronic Vest Strike): Taekwondo electronic vest strikes test is one of the important tests, especially because it carries values specific to the taekwondo branch. It has determined the techniques that are most frequently preferred in the competition by expert trainers in the field and are considered important in terms of point value. The determined techniques were performed on electronic vests. The techniques were repeated 5 times and the bars that appeared on the computer at each strike were recorded and the best score was recorded. The participants applied each technique they applied with the right and left feet (Kim, 2019).

Data Analysis

After the data was transferred electronically, extreme value analysis was first performed. Then, Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to determine whether the data showed a normal distribution. Since the amount of data in this study was over 30, the Kolmogorov-Smirnov test was used to determine whether the data showed a normal distribution (Kalaycı, 2018). Since the data did not show a normal distribution, nonparametric test techniques were used in the analyses. biomotor and technical developments of experimental group 1, experimental group 2 and control groups included in the study, Wilcoxon test was applied, and in the pre-test and post-test comparisons between groups, Kruskal-Wallis test was used. In cases where the Kruskal-Wallis test result was significant, Bonferroni test corrected from Post hoc multiple comparison tests was used to determine between which groups the difference occurred. SPSS 25.0 (IBM SPSS Corp., Armonk, NY, USA) statistical program was used in the analysis of the data and the significance level was accepted as $p<0.05$ when evaluating the analysis results.

Training Program

Experimental Group 1 (Sand Plyometric Training Group)			Experimental Group 2 (Plyometric Training Group on the Mat)
1.Week	Day 1	10 minutes warm-up 3 sets x 8 jump squats 3 sets x 10 tuck jumps 3 sets x 6 box jumps 2 minutes rest intervals	10 minutes warm-up 3 sets x 8 jump squats 3 sets x 10 tuck jumps 3 sets x 6 box jumps 2 minutes rest intervals
	Day 2	10 minutes warm up 3 sets x 10 box jumps 3 sets x 12 skater jumps 3 sets x 8 depth jumps 2 minute rest intervals	10 minutes warm up 3 sets x 10 box jumps 3 sets x 12 skater jumps 3 sets x 8 depth jumps 2 minute rest intervals
	Day 3	10 minutes warm-up 3 sets x 6 jump lunges 3 sets x 10 lateral bounds 3 sets x 12 hurdle jumps 2 minutes rest intervals	10 minutes warm-up 3 sets x 6 jump lunges 3 sets x 10 lateral bounds 3 sets x 12 hurdle jumps 2 minutes rest intervals
2.Week	Day 1	10 minutes warm-up 4 sets x 8 jump squats 4 sets x 10 tuck jumps 4 sets x 6 box jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 8 jump squats 4 sets x 10 tuck jumps 4 sets x 6 box jumps 2 minutes rest intervals
	Day 2	10 minutes warm up 4 sets x 10 single leg box jumps 4 sets x 12 skater jumps 4 sets x 8 depth jumps 2 minute rest intervals	10 minutes warm up 4 sets x 10 single leg box jumps 4 sets x 12 skater jumps 4 sets x 8 depth jumps 2 minute rest intervals
	Day 3	10 minutes warm-up 4 sets x 6 jump lunges 4 sets x 10 lateral bounds 4 sets x 12 hurdle jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 6 jump lunges 4 sets x 10 lateral bounds 4 sets x 12 hurdle jumps 2 minutes rest intervals
3.Week and 4. Week	Day 1	10 minutes warm up 4 sets x 10 jump squats 4 sets x 12 tuck jumps 4 sets x 8 box jumps 2-minute rest intervals	10 minutes warm up 4 sets x 10 jump squats 4 sets x 12 tuck jumps 4 sets x 8 box jumps 2-minute rest intervals
	Day 2	10 minutes warm up 4 sets x 12 single leg box jumps 4 sets x 14 skater jumps 4 sets x 10 depth jumps 2-minute rest intervals	10 minutes warm up 4 sets x 12 single leg box jumps 4 sets x 14 skater jumps 4 sets x 10 depth jumps 2-minute rest intervals
	Day 3	10 minutes warm-up 4 sets x 8 jump lunges 4 sets x 12 lateral bounds 4 sets x 14 hurdle jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 8 jump lunges 4 sets x 12 lateral bounds 4 sets x 14 hurdle jumps 2 minutes rest intervals
5. and 6. Week	Day 1	10 minutes warm-up 4 sets x 10 jump lunges 4 sets x 14 lateral bounds 4 sets x 16 hurdle jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 10 jump lunges 4 sets x 14 lateral bounds 4 sets x 16 hurdle jumps 2 minutes rest intervals
	Day 2	10 minutes warm up 4 sets x 10 jump squats 4 sets x 12 tuck jumps 4 sets x 8 box jumps 2-minute rest intervals	10 minutes warm up 4 sets x 10 jump squats 4 sets x 12 tuck jumps 4 sets x 8 box jumps 2-minute rest intervals
		10 minutes warm-up 4 sets x 6 jump lunges	10 minutes warm-up 4 sets x 6 jump lunges

	Day 3	4 sets x 10 lateral bounds 4 sets x 12 hurdle jumps 2 minutes rest intervals	4 sets x 10 lateral bounds 4 sets x 12 hurdle jumps 2 minutes rest intervals
7. and 8. Week	Day 1	10 minutes warm-up 4 sets x 8 jump lunges 4 sets x 12 lateral bounds 4 sets x 14 hurdle jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 8 jump lunges 4 sets x 12 lateral bounds 4 sets x 14 hurdle jumps 2 minutes rest intervals
	Day 2	10 minute warm up 4 sets x 12 single leg box jumps 4 sets x 14 skater jumps 4 sets x 10 depth jumps 2 minute rest intervals	10 minute warm up 4 sets x 12 single leg box jumps 4 sets x 14 skater jumps 4 sets x 10 depth jumps 2 minute rest intervals
	Day 3	10 minutes warm-up 4 sets x 12 jump squats 4 sets x 14 tuck jumps 4 sets x 10 box jumps 2 minutes rest intervals	10 minutes warm-up 4 sets x 12 jump squats 4 sets x 14 tuck jumps 4 sets x 10 box jumps 2 minutes rest intervals

Results

Table 2.
Comparison of Participants' Biomotor Measurements Between Groups (Pre-Test) (Kruskal Wallis)

Variables	Research Group	n	Average Rank	X^2 / KW	*p*
Speed (20 m. Speed) (sec)	Experimental Group 1	22	37.34	3.055	.358
	Experimental Group 2	22	36.75		
	Control	22	36.41		
Agility (Pro-Agility) (sec)	Experimental Group	22	38.68	5.235	.074
	Experimental Group 2	22	37.00		
	Control	22	35.82		
Vertical Vault (cm)	Experimental Group 1	22	36.48	4.641	.061
	Experimental Group 2	22	35.57		
	Control	22	33.45		
Flexibility (Sit Reach) (cm)	Experimental Group 1	22	30.70	4.350	.072
	Experimental Group 2	22	31.02		
	Control	22	30.77		
Balance (Stork Balance) (sec)	Experimental Group 1	22	32.43	3.501	.272
	Experimental Group 2	22	32.20		
	Control	22	31.86		

*p<.05; **p<.01

According to the Kruskal Wallis test results (Table 2) applied to compare the biomotor pre-test results of the athletes, no statistically significant difference was found (p>.05).

Table 3.
Intragroup (Pre-Test-Post-Test) Comparison of Participants' Biomotor Measurements (Wilcoxon)

	Variables	Measurement	n	Average Rank	Total Rank	Z	*p*
EXPERIMENTAL GROUP 1	Speed (20 m. Speed) (sec)	Negative Order	3	1.00	1	**-3.277**	**.000****
		Positive Order	19	13.00	257.00		
		Equal	0				
	Agility (Pro-Agility) (sec)	Negative Order	0	1.50	.00	**-4.310**	**.000****
		Positive Order	22	11.00	253.00		
		Equal	0				
	Vertical Jump (cm)	Negative Order	1	2.50	1.50	**-4.320**	**.009****
		Positive Order	21	16.54	145.50		
		Equal	1				
	Flexibility (Sit Reach) (cm)	Negative Order	0	.00	.00	**-4.447**	**.000****
		Positive Order	17	12.00	153.00		
		Equal	5				
	Balance (Stork Balance) (sec)	Negative Order	0	,00	,00	**-3.297**	**.000****
		Positive Order	22	11.50	253.00		
		Equal	0				
EXPERIMENTAL GROUP 2	Speed (20 m. Speed) (sec)	Negative Order	0	.50	.00	**-3.490**	**.000****
		Positive Order	17	12.50	255.00		
		Equal	5				
	Agility (Pro-Agility) (sec)	Negative Order	0	.50	.00	**-3.610**	**.000****
		Positive Order	22	13.00	257.00		
		Equal	0				
	Vertical Jump (cm)	Negative Order	3	.00	1.00	**-3.469**	**.000****
		Positive Order	18	11.50	255.00		
		Equal	1				
	Flexibility (Sit Reach) (cm)	Negative Order	0	.00	.00	**-4.127**	**.000****
		Positive Order	22	12.50	257.00		
		Equal	0				
	Balance (Stork Balance) (sec)	Negative Order	0	.00	.00	**-3.707**	**.000****
		Positive Order	22	12.50	257.00		
		Equal	0				
CONTROL GROUP	Speed (20 m. Speed) (sec)	Negative Order	7	11.26	14.50	**-3.233**	**.001****
		Positive Order	8	6.17	147.50		
		Equal	7				
	Agility (Pro-Agility) (sec)	Negative Order	3	11.00	1.50	**-3.896**	**.000****
		Positive Order	19	1.00	210.00		
		Equal	0				
	Vertical Jump (cm)	Negative Order	0	3.00	12.00	**-2.111**	**.035***
		Positive Order	12	6.00	54.00		
		Equal	10				
	Flexibility (Sit Reach) (cm)	Negative Order	0	.00	.00	**-3.838**	**.000****
		Positive Order	19	10.00	187.00		
		Equal	3				
	Balance (Stork Balance) (sec)	Negative Order	6	5.25	28.50	**-3.085**	**.002****
		Positive Order	16	13.84	229.50		
		Equal	0				

*p<.05; **p<.01

The Wilcoxon Signed Rank test was applied to determine whether there was a significant difference between the pre-test and post-test scores of the participants (Table 39).

According to the pre-test-post-test results of the participants within the groups, it was determined that there was a statistically significant difference in the speed, agility, jumping, flexibility and balance performance of the experimental group 1, experimental group 2 and control group participants according to the post-test results (p<.05).

Table 4.
Comparison of Participants' Biomotor Measurements Between Groups (Post-Test) (Kruskal Wallis)

Variables	Research Group	n	Average Rank	X^2/ KW	*p*	Bonferroni
Speed (20 m. Speed) (sec)	Experimental Group 1	22	44.70	15.386	**,000****	**1>3**
	Experimental Group 2	22	36.66			
	Control Group	22	33.14			
Agility(Pro-Agility) (sec)	Experimental Group 1	22	42.27	14.262	**,000****	**1>3**
	Experimental Group 2	22	36.41			
	Control Group	22	32.82			
Vertical Jump (cm)	Experimental Group 1	22	40.61	16.452	**,000****	**1>3**
	Experimental Group 2	22	34.41			
	Control Group	22	31.33			
Flexibility (Sit Reach) (cm)	Experimental Group 1	22	40.23	17.386	**,000****	**1>3**
	Experimental Group 2	22	30.41			
	Control Group	22	26.86			
Balance (Stork Balance) (sec)	Experimental Group 1	22	42.07	18.260	**,000****	**1>3**
	Experimental Group 2	22	35.00			
	Control Group	22	24.43			

*p<.05; **p<.01

According to the Kruskal Wallis test results (Table 4) applied to compare the biomotor post-test results of the athletes, significant results were found in speed, agility, jumping, flexibility and balance test results. According to the Bonferroni test results applied to determine which group showed more development, it was determined that the biomotor rank average of the experimental group 1 participants was higher than the experimental group 2 and control group participants.

Table 5.
Comparison of Participants' Anaerobic (Running Based Test) and Aerobic (Yo-Yo Test) Measurements Between Groups (Pre-Test) (Kruskal Wallis)

Variables	Research Group	n	Average Rank	X^2/ KW	*p*
Max. Power	Experimental Group 1	22	31.05	2.650	.158
	Experimental Group 2	22	30.10		
	Control Group	22	30.34		
Fatigue Index	Experimental Group 1	22	30.10	1.219	.750
	Experimental Group 2	22	36.73		
	Control Group	22	36.20		
Relative Power	Experimental Group 1	22	34.4	2.320	.349
	Experimental Group 2	22	32.25		
	Control Group	22	34.60		
MaxVO2	Experimental Group 1	22	34.25	2.750	.320
	Experimental Group 2	22	37.05		
	Control Group	22	36.55		

*p<.05; **p<.01

According to the Kruskal Wallis test results (Table 5) applied to compare the anaerobic and aerobic pre-test results of the athletes, no statistically significant difference was found (p>.05).

Table 6.
Intra-Group (Pre-Test-Post-Test) Comparison of Participants in Anaerobic (Running Based Test) and Aerobic (Yo-Yo Test) (Wilcoxon)

		Measurement	n	Average Rank	Total Rank	Z	*p*
Experimental group 1	Max. Power	Negative Order	3	5.00	20.00	**-3.425**	**.001****
		Positive Order	19	14.21	238.00		
		Equal	0				
	Fatigue Index	Negative Order	3	5.57	18.00	**3.400**	**.001****
		Positive Order	18	13.00	220.00		
		Equal	1				
	Relative Power	Negative Order	0	5.50	.00	**-3.667**	**.001****
		Positive Order	22	10.00	242.50		
		Equal	0				
	MaxVO2	Negative Order	0	.00	.00	**-4.319**	**.000***
		Positive Order	22	12.50	253.00		
		Equal	0				
Experimental Group 2	Max. Power	Negative Order	0	.00	.00	**-4.207**	**.000****
		Positive Order	22	12.50	253.00		
		Equal	0				
	Fatigue Index	Negative Order	5	7.00	49.00	**-4.516**	**.012****
		Positive Order	17	14.60	204.00		
		Equal	0				
	Relative Power	Negative Order	0	.00	.00	**-4.307**	**.000****
		Positive Order	22	13.50	253.00		
		Equal	0				
	MaxVO2	Negative Order	0	.00	.00	**-4.206**	**.000***
		Positive Order	22	11.50	253.00		
		Equal	0				
Control Group	Max. Power	Negative Order	2	6.33	18.00	**-3.290**	**.000****
		Positive Order	20	11.28	242.00		
		Equal	0				
	Fatigue Index	Negative Order	4	6.50	32.00	**-3.420**	**.016****
		Positive Order	18	14.00	220.00		
		Equal	0				
	Relative Power	Negative Order	3	5.00	18.00	**-3.520**	**.000****
		Positive Order	19	13.00	220.00		
		Equal	0				
	MaxVO2	Negative Order	0	.00	.00	**-4.214**	**.000***
		Positive Order	22	12.50	253.00		
		Equal	0				

*p<.05; **p<.01

Wilcoxon Signed Rank test was applied to determine whether there was a significant difference between the pre-test and post-test scores of the participants.

According to the pre-test-post-test results of the anaerobic and aerobic performances of the participants, it was determined that there was a statistically significant difference in the speed, agility, jumping, flexibility and balance performance of the experimental group 1, experimental group 2 and control group participants according to the post-test results (p<.05).

Table 7.
Comparison of Participants' Anaerobic (Running Based Test) and Aerobic (Yo-yo Test) Endurance Measurements between Groups (post-test) (Kruskal Wallis)

Variables	Research Group	n	Average Rank	X^2/ KW	*p*	Bonferroni
Max. Power	Experimental Group 1	22	41.11	.382	***.016***	**1>3**
	Experimental Group 2	22	31.60			
	Control Group	22	21.60			
Fatigue Index	Experimental Group 1	22	43.50	1.701	***.001***	**1>3**
	Experimental Group 2	22	34.00			
	Control Group	22	25.00			
Relative Power	Experimental Group 1	22	44.25	.803	***.000***	**1>3**
	Experimental Group 2	22	35.25			
	Control Group	22	30.00			
MaxVO2	Experimental Group 1	22	41.45	.882	***.000***	**1>3**
	Experimental Group 2	22	33.27			
	Control Group	22	28.84			

*p<.05; **p<.01

According to the Kruskal Wallis test results applied to compare the post-test results of the anaerobic and aerobic performances of the athletes, significant results were detected in the max. power, fatigue index, relative power and MaxVo2 test results (p<.05)**.** According to the Bonferroni test results applied to determine which group showed more development, it was determined that the mean rank of the anaerobic and aerobic performances of the experimental group 1 participants was higher than the experimental group 2 and control group participants.

Table 8.
Intergroup (Pre-Test) Comparison of Participants' Taekwondo Technical Performance Test Measurements (Kruskal Wallis)

Variables	Research Group	n	Average Rank	X^2/ KW	*p*
Palding-Chagi Right	Experimental Group 1	22	30.05	2.440	.250
	Experimental Group 2	22	31.75		
	Control Group	22	31.70		
Palding-Chagi Sol	Experimental Group 1	22	30.98	2.856	.325
	Experimental Group 2	22	32.18		
	Control Group	22	31.34		
Yop-Chagi Right	Experimental Group 1	22	30.50	.250	.560
	Experimental Group 2	22	33.15		
	Control Group	22	32.00		
Yop-Chagi Left	Experimental Group 1	22	31.85	.420	.645
	Experimental Group 2	22	30.45		
	Control Group	22	32.60		

According to the Kruskal Wallis test results applied to compare the pre-test results of the athletes' technical performances, no statistically significant difference was found (p>.05).

Table 9.
Within-Group (Pre-Test-Post-Test) Comparison of Participants' Taekwondo Technical Performance Tests (Wilcoxon)

	Variables	Measurement	n	Average Rank	Total Rank	Z	*p*
EXPERIMENTAL GROUP 1	Palding-Chagi Right	Negative Order	0	.00	.00	**-4.252**	**.000****
		Positive Order	22	20.50	243.00		
		Equal	0				
	Palding-Chagi Sol	Negative Order		.00	.00	**-3.430**	**.001****
		Positive Order	22	21.00	2451.00		
		Equal	0				
	Yop-Chagi Right	Negative Order	0	.00	.00	**-3.300**	**.000****
		Positive Order	22	21.10	233.50		
		Equal	0				
	Yop-Chagi Left	Negative Order	0	.00	.00	**-4.000**	**.000****
		Positive Order	22	21.00	251.00		
		Equal	1				
EXPERIMENTAL GROUP 2	Palding-Chagi Right	Negative Order	0	.00	.00	**-3.136**	**.000****
		Positive Order	22	21.50	253.00		
		Equal	0				
	Palding-Chagi Sol	Negative Order	0	.00	.00	**-3.220**	**.000****
		Positive Order	22	21.50	254.00		
		Equal	0				
	Yop-Chagi Right	Negative Order	0	.00	.00	**-3.170**	**.000****
		Positive Order	22	21.50	251.00		
		Equal	0				
	Yop-Chagi Left	Negative Order	0	.00	.00	**-4.175**	**.000****
		Positive Order	22	21.50	247.00		
		Equal	0				
CONTROL GROUP	Palding-Chagi Right	Negative Order	0	,00	,50	**-3.760**	**.004****
		Positive Order	22	21.50	197.50		
		Equal	0				
	Palding-Chagi Sol	Negative Order	0	,00	,00	**-3.630**	**.008****
		Positive Order	22	20.50	241.00		
		Equal	10				
	Yop-Chagi Right	Negative Order	0	,50	,00	**-3.335**	**.002****
		Positive Order	22	19.63	244.00		
		Equal	0				
	Yop-Chagi Left	Negative Order	0	.08	,50	**-3.135**	**.002****
		Positive Order	22	20.07	248.50		
		Equal	0				

**p*<.05; ***p*<.01

The Wilcoxon Signed Rank test was applied to determine whether there was a significant difference between the pre-test and post-test scores of the participants.

According to the pre-test-post-test results of the participants within the groups, it was determined that there was a statistically significant difference in the speed, agility, jumping, flexibility and balance performance of the experimental group 1, experimental group 2 and control group participants according to the post-test results (*p*<.05).

Table 10.
Comparison of Participants' Taekwondo Technical Performance Test Measurements between Groups (Post-Test) (Kruskal Wallis)

Variable	Research Group	n	Average Rank	X^2/ KW	*p*	Bonferroni
Palding-Chagi Right	Experimental Group 1	22	42.00	2.234	***.007***	**1>2**
	Experimental Group 2	22	33.50			
	Control Group	22	26.84			
Palding-Chagi Left	Experimental Group 1	22	39.07	3.525	***.007***	**1>2**
	Experimental Group 2	22	32.00			
	Control Group	22	20.00			
Yop-Chagi Right	Experimental Group 1	22	44.65	3.310	***.003***	**1>2**
	Experimental Group 2	22	33.00			
	Control Group	22	30.00			
Yop-Chagi Left	Experimental Group 1	22	48.45	2.650	***.005***	**1>2**
	Experimental Group 2	22	37.30			
	Control Group	22	31.14			

*p<.05; **p<.01

According to the Kruskal Wallis test results applied to compare the post-test results of the technical performances of the athletes, significant results were found in the paldingchagi (right and left) and yop chagi (right and left) test results. (p<.05). According to the Bonferroni test results applied to determine which group showed more development, it was determined that the technical performance average rank of the experimental group 1 participants was higher than the experimental group 2 and control group participants.

Discussion

According to the results obtained from the findings of the study, there is a significant improvement in some biomotor and technical performance parameters because of the applied training programs. It reveals that this improvement has a significant effect on the physical and technical capacities of the participants.When the pre-test results of the participants' biomotor performance parameters were examined, no significant difference was detected. This situation indicates that all groups showed equal and similar characteristics at the initial level, there was no significant difference between them, and it affects the reliability of the groups.

According to the Wilcoxon Signed Rank test conducted to examine the effects of the 8-week training programs applied to the participants on the pre-test and post-test results within the group, significant improvements were detected in speed, agility, jumping, flexibility and balance performances (p<.05). According to these results, it is shown that the training programs applied for 8 weeks contributed to some biomotor performance developments of the participants. When the literature is examined, similar results are seen in our study (Aydemir et al., 2021; Chen et al., 2022; Uzelac et al., 2020).

According to the Kruskal-Wallis test results, in which the post-test comparisons of the participants' biomotor performances were made, significant differences are seen (p<.05). According to the Bonferroni test results, which were conducted to determine which group showed more development, it was revealed that the participants in experimental group 1 showed more development than the participants in experimental group 2 and the control group. It is indicated that plyometric exercises done on sand contribute more to the development of biomotor performance in taekwondo athletes. When previous studies were examined, it was found that plyometric training increased the physical performance of athletes by improving factors such as power production and muscle elasticity (Smith et al., 2017; In addition, studies indicating that exercises performed on sand provide more power production and resistance, continuity of power produced, and development of balance on an unstable surface show more development in many performances have supported our planned training program and revealed that we can find stronger results and supported our study (Brown & Lee, 2019; Jones & Taylor, 2018).

In the study, significant differences were detected according to the post-test results of the anaerobic and aerobic parameters of the participants. According to the Bonferroni test results conducted to determine which group showed more development, it was determined that the participants in experimental group 1 (participants who did plyometric training on

the sand) showed more development than the participants in experimental group 2 and the control group. When the literature is examined, it is stated that performance parameters such as anaerobic and aerobic endurance, speed and power production are important, such as taekwondo, and these training programs provide significant contributions to performance parameters such as anaerobic and aerobic endurance, speed and power production (Williams & Jones, 2018). Since more resistance occurs in exercises done on the sand, the muscles can contract for a longer time using less oxygen. This situation causes more development (Guilherme et al., 2019). These types of exercises cause the muscle to contract faster and work at higher intensity in a short time, increasing anaerobic and aerobic performance and decreasing fatigue levels (Miller & Thompson, 2017). In addition, it is stated that exercise done on sand causes more energy consumption (Rodriguez & Diaz, 2020). These studies support our work.

According to the post-test results of the participants' technical performances, significant differences were found (p<.05). According to the Bonferroni test results conducted to determine which group showed more development, the participants in experimental group 1 (participants who did plyometric training on sand) showed more development than the participants in experimental group 2 and the control group. According to this finding, it is seen that plyometric training done on sand leads to improvements, especially in a sport where technical performance is important, such as taekwondo. When previous studies were examined, it was determined that the types of training done on sand developed some technical skills in athletes (Lee & Lee, 2021). In a study conducted by Aydemir (2021), it was found that plyometric training significantly improved the motor skills of taekwondo athletes in the 12-14 age group. The study concluded that plyometric exercises enhanced speed, agility, and balance in taekwondo techniques, and these improvements helped athletes become more successful in competitions. Such training enables athletes to apply their technical skills faster and more powerfully. In Boyanmıs (2022) research, a combination of plyometric training and blood flow restriction training was applied to taekwondo athletes aged 15-19. The study found that plyometric exercises improved the technical performance of taekwondo athletes, with noticeable improvements observed in jumping, kicking, and defensive movements used during combat.

As a result, in this study where different training types are examined, it is seen that plyometric exercises performed on sand have positive effects on biomotor and technical performance development. According to these results, it has been revealed that plyometric training on sand, which will be added to training methodologies, will play an active role especially in sports such as taekwondo where speed, power, endurance and technical skills are high.

Conclusion and Recommendation

When the results of the study were examined, significant differences and improvements were detected in the test results of some biomotor and technical performance parameters of the participants. According to the Kruskal-Wallis test results in the study, no significant difference was found in the biomotor pre-test results of the participants between the groups (p>0.05). The fact that no significant differences were found in the pre-test results of the participants indicates that there was no significant difference within the group and that the participants had similar characteristics.

According to the Wilcoxon Signed Ranks test results, in which the pre-test-post-test comparison of the participants within the groups was made, significant differences were found in the performance parameters of speed, agility, jumping, flexibility and balance (p<.05). According to these findings, it is shown that there was a significant improvement in the performances of each group in the training programs applied to the participants for 8 weeks. According to the Kruskal-Wallis test results, which were conducted to compare some biomotor post-test measurements of the participants, significant differences were detected (p<.05). According to the Bonferroni test results, which were conducted to determine which group showed more development, it was observed that the participants of Experimental Group 1 showed more development than the participants of Experimental Group 2 and Control Group. In this case, it was found that plyometric training done on sand contributed more to the development of some biomotor performance of taekwondo athletes.

When the post-test results of the participants' anaerobic and aerobic performance parameters were compared with the Kruskal-Wallis test, significant differences were also found in the max. power, fatigue index, relative power and MaxVo2 tests (p<.05). According to the Bonferroni test results, which were conducted to determine which group showed more development, the performances of the experimental group 1 participants showed more development than the anaerobic and aerobic performances of the experimental group 2 and control group participants. This indicates that the training program of

the experimental group 1 was more effective.

In terms of examining the post-test measurements of the athletes' technical performance, significant differences were found in the Kruskal-Wallis test, palding chagi (right and left) and yop chagi (right and left) tests (p<.05). According to the Bonferroni test results, which were conducted to determine which group showed more development, the technical performance development of the experimental group 1 participants was more pronounced than the technical performance developments of the experimental group 2 and control group participants, and this group showed more progress against the other two groups.

According to these results, some suggestions can be made to maximize the performance development of athletes.

- Considering that the participants of the experimental group 1 (participants who did plyometric exercises on the sand) showed more development, the training program applied by this group can be adapted to the training programs. The training program applied by reaching a larger audience can produce more beneficial results.
- According to the test results applied to the participants, some technical performances showed results in favor of the experimental group 1 participants (participants who did plyometric exercises on sand). Especially in the development of direct throwing techniques such as yopchagi and paldingchagi, the addition of these training programs to taekwondo training programs may produce more beneficial results.
- Considering that the training program applied to the participants of experimental group 1 (plyometric training done on sand) showed more development, more efficient results can be obtained by planning individual studies by considering individual differences during the training.
- The diversity of the study can be increased by conducting studies in different age groups.
- Developments in different branches can be followed through studies conducted in different branches.
- By conducting long-term studies, athletes' performances can be examined holistically throughout the year.
- coach seminars and national team camps for the work to become a more qualified and sustainable identity.
- In conclusion, this study has shown that a proper training program provides significant improvements in the biomotor and technical performances of athletes. However, it can be said that to increase these improvements, the training should be more customized and the differences within the group should be considered.

Etik Komite Onayı: Bu çalışma için etik komite onayı Bayburt Üniversitesi (Tarih: 4 Kasım 2024, Karar No: E-15604681-100-236987) ile alınmıştır.
Hasta Onamı: Çalışmaya katılan tüm katılımcılardan sözlü onam alınmıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir-B.A; Tasarım-B.A; Denetleme-M.K; Kaynaklar-M.K; Veri Toplanması ve/veya İşlemesi B.A; Analiz ve/ veya Yorum-M.K; Literatür Taraması-M.K; Yazıyı Yazan-B.A; Eleştirel İnceleme-M.K
Çıkar Çatışması: Yazarlar, çıkar çatışması olmadığını beyan etmiştir.
Finansal Destek: Yazarlar, bu çalışma için finansal destek almadığını beyan etmiştir.

Ethics Committee Approval: Ethics committee approval for this study was received from Bayburt University (Date: 4 November 2024, Decision No: E-15604681-100-236987).
Informed Consent: Verbal consent was obtained from all the participants.
Peer-review: Externally peer-reviewed.
Author Contributions: Concept -B.A; Design-B.A; Supervision-M.K; Resources-M.K; Data Collection and/or Processing-B.A; Analysis and/or Interpretation-M.K; Literature Search-M.K; Writing Manuscript-B.A; Critical Review-M.K.
Conflict of Interest: The authors have no conflicts of interest to declare.
Financial Disclosure: The authors declared that this study has received no financial support.

References

Apollaro, G., Panascì, M., Ouergui, I., Falcó, C., Franchini, E., Ruggeri, P., & Faelli, E. (2024). Influence of body composition and muscle power performance on multiple frequency speed of kick test in taekwondo athletes. *Sports (Basel, Switzerland)*, *12*(12), 322. https://doi.org/10.3390/sports12120322

Aydemir, B., Yüksek, S., Ölmez, C., & Şar, H. (2021). Taekwondo temalı pliometrik antrenmanların 12-14 yaş taekwondo sporcularının motorik özellikleri üzerine etkisi. *Uluslararası Güncel Eğitim Araştırmaları Dergisi*, *7*(1), 335–351.

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of Sports Sciences*, *33*(15), 1574–1579.https://doi.org/10.1080/02640414.2014.996184

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, *38*(1), 37–51. https://doi.org/10.2165/00007256-200838010-00004

Bedoya, A. A., Miltenberger, M. R., & Lopez, R. M. (2015). Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review. *Journal of strength and conditioning research, 29*(8), 2351–2360. https://doi.org/10.1519/JSC.0000000000000877

Behm, D. G., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. *Journal of Strength and Conditioning Research, 25*(3), 739–748. https://doi.org/10.1519/JSC.0b013e3181b3df32

Binnie, M. J., Dawson, B., Pinnington, H., Landers, G., & Peeling, P. (2014). Sand training: a review of current research and practical applications. *Journal of sports sciences*, *32*(1), 8–15. https://doi.org/10.1080/02640414.2013.805239

Boyanmış, A., & Akın, M. (2020). Taekwondocularda kan akımı kısıtlama antrenmanlarının kuvvet gelişimine etkisi. *Dünya Sağlık ve Tabiat Bilimleri Dergisi, 3*(3), 117–122.

Bridge, C.A., Ferreira da Silva Santos, J., Chaabène, H. *et al.* Physical and Physiological Profiles of Taekwondo Athletes. *Sports Med 44*, 713–733 (2014). https://doi.org/10.1007/s40279-014-0159-9

Chen, C. F., & Wu, H. J. (2022). The effect of an 8-week rope skipping intervention on standing long jump performance. *International Journal of Environmental Research and Public Health*, *19*(14), 8472. https://doi.org/10.3390/ijerph19148472

Chen, L., Zhang, Z., Huang, Z., Yang, Q., Gao, C., Ji, H., Sun, J., & Li, D. (2023). Meta-analysis of the effects of plyometric training on lower limb explosive strength in adolescent athletes. *International Journal of Environmental Research and Public Health*, *20*(3), 1849. https://doi.org/10.3390/ijerph20031849

de Villarreal, E. S., Rascón, P. B., Becerra, M. O., Calleja-González, J., Alcaraz, P. E., Feito-Blanco, J., & Ramirez-Campillo, R. (2023). Effects of Sand Surface Plyometric and Sprint Training on Physical and Technical Skill Performance in Beach Handball *Players. Journal of human kinetics, 90*, 227–237. https://doi.org/10.5114/jhk/169519

Fiorilli, G., Mariano, I., Iuliano, E., Giombini, A., Ciccarelli, A., Buonsenso, A., . . . Cagno, A. d. (2020). Isoinertial eccentric-overload training in young soccer players: Effects on strength, sprint, change of direction, agility and soccer shooting precision. Journal of sports science and medicine, 19(1), S. 213-223. https://www.jssm.org/hf.php?id=jssm-19-213.xml

Hammami, M., Bragazzi, N.L., Hermassi, S. et al. The effect of a sand surface on physical performance responses of junior male handball players to plyometric training. *BMC Sports Sci Med Rehabil 12*, 26 (2020). https://doi.org/10.1186/s13102-020-00176-x

Harman, E., Garhammer, J., & Pandorf, C. (2000). Administration, scoring, and interpretation of selected tests. In T. R. Baechle & R. W. Earle (Eds.), *Essentials of strength training and conditioning* (pp. 287–317). Human Kinetics.

Harris MB and Kuo C-H (2021) Scientific Challenges on Theory of Fat Burning by Exercise. *Front. Physiol.* 12:685166. doi: 10.3389/fphys.2021.685166

Kalaycı, Ş. (2018). *SPSS uygulamalı çok değişkenli istatistik teknikleri* (8. baskı). Ankara: Asil Yayın Dağıtım. ISBN: 978-975-9091-14-9.

Karakoç, B., Akalan, C., Alemdaroğlu, U., & Arslan, E. (2012). The relationship between the Yo-Yo tests, anaerobic performance and aerobic performance in young soccer players. *Journal of Human Kinetics*, *35*, 81–88. https://doi.org/10.2478/v10078-012-0081-x

Lee, J., & Lee, M. (2021). Effect of plyometric training on technical skills in martial arts. *Asian Journal of Sports Science, 15(*6), 112–120.

Lemay, V., Hoolahan, J., & Buchanan, A. (2019). Impact of yoga and meditation intervention on students' stress and anxiety levels. *American Journal of Pharmaceutical Education*, *83*(5), 7001. https://doi.org/10.5688/ajpe7001

Malina, R. M., Rogol, A. D., Cumming, S. P., Coelho e Silva, M. J., & Figueiredo, A. J. (2015). Biological maturation of youth athletes: Assessment and implications. *British Journal of Sports Medicine*, *49*(13), 852–859. https://doi.org/10.1136/bjsports-2015-094623

Mertens, D. (2015). Research and evaluation in education and psychology: *Integrating diversity with quantitative, qualitative, and mixed methods* (3rd ed.). Sage Publications. ISBN: 978-1412971904

Moran, J., Ramirez-Campillo, R., Liew, B., Chaabene, H., Behm, D. G., García-Hermoso, A., Izquierdo, M., & Granacher, U. (2021). Effects of vertically and horizontally orientated plyometric training on physical performance: A meta-analytical comparison. *Sports Medicine (Auckland, N.Z.)*, *51*(1), 65–79. https://doi.org/10.1007/s40279-020-01340-6

Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International Journal of Sports Physiology and Performance*, *13*(5), 538–561. https://doi.org/10.1123/ijspp.2018-0093

Negra, Y., Chaabene, H., Sammoud, S., Bouguezzi, R., Abbes, M. A., Hachana, Y., & Granacher, U. (2017). Effects of plyometric training on physical fitness in prepuberal soccer athletes. *International Journal of Sports Medicine*, *38*(5), 370–377. https://doi.org/10.1055/s-0042-122337

Ojeda-Aravena, A., Herrera-Valenzuela, T., Valdés-Badilla, P., Báez-San Martín, E., Thapa, R. K., & Ramirez-Campillo, R. (2023). A systematic review with meta-analysis on the effects of plyometric-jump training on the physical fitness of combat sport athletes. *Sports (Basel, Switzerland)*, *11*(2), 33. https://doi.org/10.3390/sports11020033

Oliver, J. L., Ramachandran, A. K., Singh, U., Ramirez-Campillo, R., & Lloyd, R. S. (2024). The effects of strength, plyometric and combined training on strength, power and speed characteristics in high-level, highly trained male youth soccer players: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.)*, *54*(3), 623–643. https://doi.org/10.1007/s40279-023-01944-8

Ölmez, C., Aydemir, B., & Ölmez, S. N. (2022). Taekwondo tekme performansını etkileyen faktörlerin belirlenmesi. *Mediterranean Journal of Sport Science*, *5*(2), 192–209. https://doi.org/10.38021/asbid.1095173

Pardos-Mainer, E., Lozano, D., Torrontegui-Duarte, M., Cartón-Llorente, A., & Roso-Moliner, A. (2021). Effects of strength vs. plyometric training programs on vertical jumping, linear sprint and change of direction speed performance in female soccer players: A systematic review and meta-analysis.

International Journal of Environmental Research and Public Health, *18*(2), 401. https://doi.org/10.3390/ijerph18020401

Ramirez-Campillo, R., Alvarez, C., Gentil, P., Loturco, I., Sanchez-Sanchez, J., Izquierdo, M., Moran, J., Nakamura, F. Y., Chaabene, H., & Granacher, U. (2020). Sequencing effects of plyometric training applied before or after regular soccer training on measures of physical fitness in young players. *Journal of Strength and Conditioning Research, 34*(7), 1959–1966. https://doi.org/10.1519/JSC.0000000000002525

Rinaldo, N., Toselli, S., Gualdi-Russo, E., Zedda, N., & Zaccagni, L. (2020). Effects of anthropometric growth and basketball experience on physical performance in pre-adolescent male players. *International Journal of Environmental Research and Public Health, 17*(7), 2196. https://doi.org/10.3390/ijerph17072196

Sevinç, D., & Çolak, M. (2019). The effect of electronic body protector and gamification on the performance of taekwondo athletes. *International Journal of Performance Analysis in Sport, 19*(1), 110–120. https://doi.org/10.1080/24748668.2019.1570457

Silva, A. F., Clemente, F. M., Lima, R., Nikolaidis, P. T., Rosemann, T., & Knechtle, B. (2019). The effect of plyometric training in volleyball players: A systematic review. *International Journal of Environmental Research and Public Health*, *16*(16), 2960. https://doi.org/10.3390/ijerph16162960

Singh, G., Kushwah, G. S., Singh, T., Thapa, R. K., Granacher, U., & Ramirez-Campillo, R. (2022). Effects of sand-based plyometric-jump training in combination with endurance running on outdoor or treadmill surface on physical fitness in young adult males. *Journal of Sports Science & Medicine*, *21*(2), 277–286. https://doi.org/10.52082/jssm.2022.277

Stojanović, E., Ristić, V., McMaster, D. T., & Milanović, Z. (2017). Effect of plyometric training on vertical jump performance in female athletes: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.)*, *47*(5), 975–986. https://doi.org/10.1007/s40279-016-0634-6

Şimşek, A. (2018). Araştırma modelleri. Ali Şimşek (Ed.). Sosyal bilimlerde araştırma yöntemleri içinde (80-106). Eskişehir: Anadolu Üniversitesi.

Uzelac-Sciran, T., Sarabon, N., & Mikulic, P. (2020). Effects of 8-Week Jump Training Program on Sprint and Jump Performance and Leg Strength in Pre- and Post-Peak Height Velocity Aged Boys. *Journal of sports science & medicine, 19*(3), 547–555.

Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *Journal of Strength and Conditioning Research*, *23*(6), 1820–1827. https://doi.org/10.1519/JSC.0b013e3181b3df32