

Araştırma Makalesi

6 HAFTALIK PLİOMETRİK ANTRENMANLARIN FUTSALCILARDA BAZI PERFORMANS PARAMETRELERİ ÜZERİNE ETKİSİNİN İNCELENMESİ*

INVESTIGATION OF THE EFFECTS OF 6 WEEKS PLYOMETRIC TRAININGS ON SOME PERFORMANCE PARAMETERS ON FUTSAL PLAYERS

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6 Haftalık Pliometrik Antrenmanların Futsalçılarda Bazı Performans Parametreleri Üzerine Etkisinin İncelenmesi

ÖZ

Bu araştırma, 17-19 yaş aralığındaki erkek futsal oyuncularında altı haftalık pliometrik antrenmanların çeşitli performans değişkenleri üzerindeki etkilerini incelemek amacıyla gerçekleştirilmiştir. Çalışmaya herhangi bir sağlık sorunu bulunmayan, son dört yıldır kulüp düzeyinde lisanslı olarak ve okul sporları kapsamında düzenli şekilde müsabakalara katılan 30 gönüllü sporcu dâhil edilmiştir. Bu sporcular, 2021-2022 sezonunda futsal branşında final oynamış olan İğdir 125. Yıl Anadolu Lisesi ile Mehmet Murat İşler Sosyal Bilimler Lisesi'nden seçilmiştir. Katılımcılar 15 kişilik deney ve 15 kişilik kontrol grubu olarak ikiye ayrılmıştır. Her iki grup da düzenli futsal antrenmanlarına devam ederken, deney grubu ayrıca haftada üç gün olmak üzere toplam altı hafta süresince ek pliometrik antrenman programına tabi tutulmuştur. Araştırma süresince her iki grubun boy, kilo, vücut kütle indeksi, 30 metre sürat, dikey sıçrama, esneklik ve çeviklik ölçümleri hem çalışma öncesinde (ön test) hem de sonrasında (son test) yapılmıştır. Elde edilen verilerde tüm değişkenlerin ortalama ve standart sapma değerleri hesaplanmıştır. Verilerin normal dağılıma uygunluğu Shapiro-Wilk testiyle değerlendirilmiş, normallik şartlarının sağlanması üzerine grup içi analizlerde bağımlı örneklem t testi, grup karşılaştırmalarında ise bağımsız örneklem t testi kullanılmıştır. İstatistiksel analizler SPSS 25 programıyla gerçekleştirilmiş ve anlamlılık düzeyi $p < 0.05$ olarak kabul edilmiştir. Deney grubunun ön test ve son test bulguları karşılaştırıldığında istatistiksel olarak anlamlı farklılıklar saptanmıştır ($p < 0.05$). Sonuç olarak, altı haftalık pliometrik antrenman programının performans parametreleri üzerinde olumlu etkiler yarattığı belirlenmiştir. Bu sonuçlar doğrultusunda, futsal branşında görev yapan antrenörlerin sezon içi veya sezon öncesi hazırlık dönemlerinde pliometrik antrenmanlara yer vermeleri, oyuncuların sürat, dikey sıçrama, esneklik ve çeviklik gibi performans parametrelerini geliştirmede etkili bir yöntem olabilir.

Anahtar Kelimeler: Futsal, performans, pliometrik, anaerobik güç, sürat

Investigation of the Effects of 6 Weeks Plyometric Trainings on Some Performance Parameters on Futsal Players

ABSTRACT

This study was conducted to examine the effects of a six-week plyometric training program on various performance parameters in male futsal players aged 17 to 19. The study included 30 volunteer athletes who had no known health problems and had been regularly participating in competitions for the past four years as licensed players at the club level and within school sports programs. These athletes were selected from İğdir 125th Year Anatolian High School and Mehmet Murat İşler Social Sciences High School, both of which reached the finals in the futsal branch during the 2021-2022 season. The participants were divided into two groups: an experimental group of 15 and a control group of 15. While both groups continued their regular futsal training routines, the experimental group additionally performed plyometric exercises three times a week for six weeks. Pre-test and post-test measurements were taken for both groups, including height, weight, body mass index, 30-meter sprint, vertical jump, flexibility, and agility tests. The means and standard deviations for all variables were calculated. To assess the normality of the data, the Shapiro-Wilk test was used. Since the data were normally distributed, paired sample t-tests were used for within-group comparisons and independent sample t-tests for between-group comparisons. All statistical analyses were performed using SPSS version 25, with the significance level set at $p < 0.05$. In the experimental group, a statistically significant difference was found between pre-test and post-test results ($p < 0.05$). As a result, it was concluded that the six-week plyometric training program had a positive effect on performance parameters. Based on these results, it is recommended that futsal coaches incorporate plyometric training, particularly during pre-season or in-season conditioning, to enhance players' speed, vertical jump, flexibility, and agility performance.

Keywords: Futsal, performance, plyometric, anaerobic power, speed

INTRODUCTION

Throughout the human lifespan, the inherent drive for survival, competition, self-realization, and curiosity has consistently influenced behavior¹. These fundamental motivations have not only led to diverse endeavors but, in conjunction with technological advancements driven by human intellect, have also contributed to the emergence and development of various modern sports disciplines².

Futsal, recognized at the international level by both UEFA and FIFA, is an officially sanctioned form of indoor football and is widely regarded as a significant and highly popular sport worldwide^{3,4}. Compared to traditional football, futsal involves fewer players, a smaller playing area, and shorter match durations, all of which require players to remain actively engaged for extended periods⁵. The confined playing space, in particular, necessitates more frequent movement, quicker positioning, rapid decision-making and execution, and frequent one-on-one encounters with opponents⁶. Essential characteristics of futsal players include the ability to effectively apply both offensive and defensive principles such as passing and support, depth, width, space creation, coverage, support play, concentration, balance, communication, mobility, and positional interchange along with creativity and a high level of game intelligence³.

For futsal players to achieve high-level performance, speed and agility are crucial physical attributes; however, endurance also plays a vital role. Therefore, training aimed at improving speed, agility, and endurance is of great importance for futsal athletes^{7,8,9}. Futsal is one of the sports in which anaerobic power and capacity key determinants of athletic performance are heavily utilized¹⁰. During futsal matches, players typically engage in high-intensity efforts lasting between 3 and 6 minutes. To cope with this intensity, athletes must possess well-developed anaerobic power and capacity¹¹. For instance, while a youth football player may interact with the ball approximately 15 times per match on a full-size pitch, this number exceeds 40 in futsal. Moreover, as in football, a significant proportion of goals scored in futsal result from motor tasks involving rapid linear movement, jumping efforts, swift maneuvering, and striking actions¹².

Plyometric training, derived from Greek roots meaning "increase" or "excessive measure" (from *plio* and *metric*), emerged as a training method initially used in individual sports during the 1970s and later adopted in the 1980s for sports that require anaerobic power¹³. Plyometrics refers to a series of movements such as jumping, bounding, and throwing, performed without additional weights, aimed at enhancing an athlete's power and explosive strength to achieve optimal performance¹⁴.

The concept of "power," which forms the foundation of many sports disciplines, results from the combination of speed and strength¹⁵. Plyometric exercises aim to enhance an athlete's muscular strength and reduce reaction time by inducing a powerful contraction following a rapid eccentric muscle action¹⁶. In essence, this training method facilitates the development of explosive power by enabling the target muscles to contract and relax maximally within the shortest possible time¹⁷. Considering that performance-related skills such as speed, jumping, sudden acceleration, and changes in direction are closely linked to anaerobic power and capacity, this study is considered significant in terms of evaluating the potential contributions of plyometric training to futsal performance.

The aim of this study is to contribute to the evolving field of sports training science by examining the effects of plyometric training on flexibility, vertical jump, agility, and speed performance parameters in futsal players, and to enhance both individual and team success by developing methods that improve athletic performance.

MATERIAL AND METHODS

In this study, the effects of a plyometric training program on certain performance variables were examined in male futsal players aged 17 to 19. An experimental design based on a pre-test/post-test model with a control group was employed. The research was conducted in accordance with the approval of the Iğdır University Scientific Research and Publication Ethics Committee (Approval No: 2021/31).

Research Design and Participant Group

The population of this study consisted of male futsal players aged 17 to 19 residing in Iğdır, Türkiye. A pre-test/post-test design was used to evaluate the effects of a six-week plyometric training program on selected performance parameters in youth male athletes within the U17-U19 age group. A total of 30 athletes (15 in the experimental group and 15 in the control group) voluntarily participated in the study. The participants were randomly assigned to either the experimental or control group using a simple randomization method. These participants were licensed futsal players who had been actively involved in club teams for the past four years and regularly competed in school sports events. They also represented Iğdır 125th Year Anatolian High School and Mehmet Murat İşler Social Sciences High School in the futsal finals during the 2021-2022 season. Participants were selected based on their voluntary consent. While the control group continued with regular futsal training only, the experimental group additionally followed a six-week plyometric training program. The objectives of the study were clearly explained to the 15 athletes in the experimental group to ensure their active and motivated participation.

Within the scope of the study, anthropometric measurements such as age, height, weight, and body mass index were recorded for male athletes in the U17-U19 age group. To assess fundamental motor characteristics, the 30-meter sprint test, vertical jump test, sit-and-reach flexibility test, and Illinois agility test were administered. Pre-test measurements were conducted prior to the plyometric training program, and post-test measurements were taken upon completion of the program. At the end of the six-week training period, changes in selected physical performance variables of the athletes were analyzed.

Applied Tests and Training Program

Height and Body Weight Measurements

To measure the athletes' height and body weight, a device with 0.01 precision approved and used by the Ministry of Youth and Sports during school talent identification programs was utilized. During the measurements, athletes were instructed to wear only shorts and t-shirts, and to remove their shoes, with measurements taken while wearing socks.

Body Mass Index (BMI) Values

The Body Mass Index of the athletes was calculated by dividing their body weight (in kilograms) by the square of their height (in meters), using the formula $BMI = \text{kg}/\text{m}^2$. The results obtained through this formula were used for evaluation.

BMI <18.5: Underweight

BMI between 18.5 and 24.9: Normal (Healthy) Weight

BMI between 25 and 29.9: Overweight

BMI \geq 30: Obese

Vertical Jump Test

Vertical jump measurements were conducted using a jump meter device commonly used in school-based talent identification programs and approved by the Ministry of Youth and Sports. The device used was the Newtest Powertimer Jump Mat (Newtest Oy, Finland), which measures flight time to estimate jump height using a pressure-sensitive platform. Each athlete stood on the mat in a half-squat position, hands on hips, and performed a vertical jump at a self-selected time without any external command. The test was completed by landing back onto the device. Each participant performed two jumps, and the best height was recorded. All jumps were performed while wearing futsal shoes.

30-Meter Sprint Test

To minimize the risk of injury and obtain accurate results, all athletes completed a warm-up routine prior to testing. When ready, each athlete began the sprint from a position one step behind the starting photocell, initiating the test without any external command. The athletes completed the 30-meter sprint by running through the two photocell gates positioned at the start and finish. The test was performed wearing a t-shirt, shorts, and indoor sports shoes. Each athlete was given two attempts with adequate rest intervals, and the best time was recorded.

Sit-and-Reach Flexibility Test

The sit-and-reach flexibility test was conducted using a standardized wooden flexibility box commonly used in school-based talent identification programs and approved by the Ministry of Youth and Sports. The test bench measured 35 cm in height, 45 cm in width, and 55 cm in top-surface length, with a 0-50 cm ruler placed 15 cm beyond the foot-contact line on the top surface. Each participant sat on the floor with both legs fully extended and feet flat against the front of the box. After confirming that the participant was wearing comfortable clothing, posture was checked. With arms extended upward and one hand placed over the other, the athlete was asked to reach forward toward the measurement scale, keeping the knees extended. The farthest point reached by the fingertips was recorded in centimeters after a 1-2 second hold at the endpoint. Each participant performed two attempts, and the best score was recorded for analysis. This protocol was adapted from Tamer (2000), a widely accepted national reference in field testing¹⁸.

Illinois Agility Test

To assess athletes' agility, an Illinois agility test setup was installed in the sports hall, consisting of a 10-meter-long and 5-meter-wide course with four cones placed in a straight line at 3.3-meter intervals in the center. Photocell timing gates were positioned at both the starting and finishing points of the course. After a general introduction to the test layout, athletes were allowed to perform 3 to 4 low-intensity trial runs. Following

a 5-6 minute warm-up period, each athlete began the test from a standing start position, one step behind the starting photocell. They navigated through the cones in a predetermined pattern, aiming to complete the course in the shortest time possible. Each athlete was given two attempts, and the best time was recorded. The Illinois agility test includes approximately 40 meters of straight running and 20 meters of slalom running between cones, incorporating five full 180-degree turns and six partial directional changes. It is noted that, in terms of both distance and duration, the Illinois test is one of the most demanding agility assessments¹⁹.

Applied Training Program

During the six-week training period, while the control group performed only regular futsal training, the experimental group engaged in an additional plyometric training session following their warm-up routines. The plyometric training was conducted at the indoor gymnasium of İğdir Mehmet Murat İşler Social Sciences High School, three times per week (Monday, Wednesday, and Friday) over a six-week period. In the first four weeks, the exercises were performed as outlined in the corresponding table, totaling 196 jumps and bounds. During the fifth and sixth weeks, the number of repetitions for each movement was increased to three sets, resulting in a total of 294 jumps and bounds. A work-to-rest ratio of 1:5 was implemented to ensure the quality and effectiveness of each jump and bound. Additionally, rest periods of 4-5 minutes were provided between sets to maximize training efficiency.

Table 1. Content of the Plyometric Training Program (First 4 Weeks)

Plyometric Exercise Protocol	Jump Count	Repetitions	Sets	Total Jumps
Forward double-leg jumps and landings (kangaroo jumps)	5	2	2	20
Box jumps and landings	6	2	2	24
Forward alternating right-left skipping	6	2	2	24
Double-leg forward jumps over hurdles	4	2	2	16
Single-leg lateral bounds (right-left)	6	2	2	24
Standing lateral double-leg jumps over a hurdle	7	2	2	28
Single-leg forward and backward hurdle jumps	9	2	2	36
Triple-directional double-leg hurdle jumps (forward, right, left, jump pool)	6	2	2	24

Table 2. Content of the Plyometric Training Program (Weeks 5 and 6)

Plyometric Exercise Protocol	Jump Count	Repetitions	Sets	Total Jumps
Forward double-leg jumps and landings (kangaroo jumps)	5	3	2	30
Box jumps and landings	6	3	2	36
Forward alternating right-left skipping	6	3	2	36
Double-leg forward jumps over hurdles	4	3	2	24
Single-leg lateral bounds (right-left)	6	3	2	36
Standing lateral double-leg jumps over a hurdle	7	3	2	42
Single-leg forward and backward hurdle jumps	9	3	2	54
Triple-directional double-leg hurdle jumps (forward, right, left, jump pool)	6	3	2	36

Statistical Analysis

The mean and standard deviation values for all variables in the study were calculated. The Shapiro-Wilk test was used to assess whether the data followed a normal distribution. Since the data were found to be normally distributed, the paired samples

t-test was employed for within-group (pre-test and post-test) comparisons, while the independent samples t-test was used for between-group comparisons. All statistical analyses were conducted using SPSS version 25, and the level of significance was set at $p < 0.05$.

RESULTS

Table 3. Descriptive Statistics of Futsal Players

Anthropometric Variables	Groups	n	\bar{x}	Sd
Age (years)	Experimental	15	17.66	0.21
	Control	15	17.80	0.17
Height (cm)	Experimental	15	171.26	1.18
	Control	15	172.40	1.62
Body Weight (kg)	Experimental	15	60.33	1.82
	Control	15	60.86	1.27
Body Mass Index (kg/m ²)	Experimental	15	20.52	0.48
	Control	15	20.36	0.44
Training Age (years)	Experimental	15	4.26	0.37
	Control	15	4.06	0.33

Table 3 displays descriptive data on participants' anthropometric characteristics, including their age, stature, body weight, BMI, and years of training experience of the players in the experimental and control groups. The average age of the 15 participants in the experimental group was calculated as 17.66 ± 0.21 years; average height as 171.26 ± 1.18 cm; average body weight as 60.33 ± 1.82 kg; average body mass index as 20.52 ± 0.48 kg/m²; and average training age as 4.26 ± 0.37 years. For the 15 athletes in the control group, the average age was determined as 17.80 ± 0.17 years; average height as 172.40 ± 1.62 cm; average body weight as 60.86 ± 1.27 kg; average body mass index as 20.36 ± 0.44 kg/m²; and average training age as 4.06 ± 0.33 years.

Table 4. Inter-Group Comparison of Flexibility Test Results

Flexibility (cm)	Experimental Group	Control Group	t	P
Pre-Test	28.53 \pm 1.10	29.20 \pm 1.75	2.17	0.03*
Post-Test	30.66 \pm 1.05	29.80 \pm 1.63	3.22	0.02*

* $p < 0.05$

When Table 4 is examined, it is observed that there are statistically significant differences between the experimental and control groups in both the pre-test and post-test flexibility scores ($p < 0.05$).

Table 5. Intra-Group Comparison of Flexibility Test Results

Flexibility (cm)	Pre-Test	Post-Test	t	P
Experimental Group	28.53 \pm 1.10	30.66 \pm 1.05	3.38	0.01*
Control Group	29.20 \pm 1.75	29.80 \pm 1.63	0.52	0.92

* $p < 0.05$

According to the within-group comparisons of initial and final assessments flexibility scores presented according to Table 5, a meaningful statistical variation was identified in the experimental group ($p < 0.05$). In contrast, no significant difference was found between the pre-test and post-test flexibility results in the control group ($p > 0.05$)

Table 6. Inter-Group Comparison of Vertical Jump Test Results

Vertical Jump (cm)	Experimental Group	Control Group	T	P
Pre-Test	34.43±1.16	33.28±1.42	1.93	0.02*
Post-Test	36.60±1.19	33.82±1.26	2.86	0.01*

*p<0.05

When the between-group comparisons of pre-test and post-test vertical jump scores in Table 6 are examined, statistically significant differences were found between the experimental and control groups in both test results (p<0.05).

Table 7. Intra-Group Comparison of Vertical Jump Test Results

Vertical Jump (cm)	Pre-Test	Post-Test	t	P
Experimental Group	34.43±1.16	36.60±1.19	5.27	0.01*
Control Group	33.28±1.42	33.82±1.26	0.14	0.84

*p<0.05

When Table 7 is examined, a statistically significant difference is observed between the pre-test and post-test vertical jump scores of the experimental group (p<0.05). On the other hand, no significant change was detected between the vertical jump test results in the control group (p>0.05).

Table 8. Inter-Group Comparison of 30 m Sprint Test Results

30 m Sprint (s)	Experimental Group	Control Group	t	P
Pre-Test	4.49±0.07	4.68±0.03	2.19	0.01*
Post-Test	4.43±0.05	4.64±0.04	1.76	0.01*

*p<0.05

When Table 8 is examined, statistically significant differences were found between the experimental and control groups in both the pre-test and post-test 30-meter sprint results (p<0.05).

Table 9. Intra-Group Comparison of 30 m Sprint Test Results

30 m Sprint (s)	Pre-Test	Post-Test	t	P
Experimental Group	4.49±0.07	4.43±0.05	4.22	0.01*
Control Group	4.68±0.03	4.64±0.04	0.57	0.96

*p<0.05

According to the within-group comparison of the 30-meter sprint tests presented in Table 9, a statistically significant difference was observed between the pre-test and post-test results in the experimental group (p<0.05). In contrast, no significant difference was found between these test results in the control group (p>0.05).

Table 10. Inter-Group Comparison of Agility Test Results

Agility (s)	Experimental Group	Control Group	t	P
Pre-Test	18.12±0.19	18.54±0.28	2.68	0.03*
Post-Test	17.10±0.18	18.33±0.27	1.36	0.02*

*p<0.05

When Table 10 is examined, statistically significant differences were found between the experimental and control groups in both the pre-test and post-test agility measurements ($p < 0.05$).

Table 11. Intra-Group Comparison of Agility Test Results

Agility (s)	Pre-Test	Pro-Test	t	P
Experimental Group	18.12±0.19	17.10±0.18	5.76	0.02*
Control Group	18.54±0.28	18.33±0.27	0.82	0.75

* $p < 0.05$

When the within-group comparisons of agility test results in Table 11 are examined, a statistically significant difference was observed between the pre-test and post-test scores in the experimental group ($p < 0.05$). However, no significant change was found between the two tests in the control group ($p > 0.05$).

DISCUSSION

With each passing day, various training methods are being developed across all sports disciplines to maximize both individual and team performance. Plyometric training is considered to be one of these methods¹². In futsal where, in addition to technical skills, the concept of "power," defined as the integration of strength and speed is a key determinant incorporating plyometric exercises may be of particular importance²⁰. This study was conducted to investigate the effects of a six-week plyometric training program on selected performance parameters in male futsal players aged 17 to 19. The athletes underwent evaluation through a 30-meter sprint, vertical jump, sit-and-reach flexibility, and Illinois agility tests, and the results were evaluated through pre- and post-test comparisons.

The Effects of Plyometric Training on Flexibility Performance

Ateş et al. (2007)²¹ evaluated the effects of a 10-week plyometric training program on certain performance parameters in football players aged 16-18. In their study, the flexibility score of the control group increased from 23.50 cm in the pre-test to 24.66 cm in the post-test, corresponding to a 4.94% improvement. Baseline flexibility data in the experimental group was recorded as 26.33 cm, which increased by 15.4% to 30.29 cm in the post-test²¹. Similarly, Karadenizli (2013)²² conducted a 12-week plyometric training program, performed twice per week by handball players, and reported a significant improvement in flexibility from 25.69±6.63 cm in the pre-test to 30.90±8.33 cm in the post-test²². Supporting the findings of the present study, Bavlı (2009)²³ demonstrated that both pool-based and field-based plyometric training programs are effective in improving flexibility, based on a study involving 91 athletes consisting of both male and female participants²³. Similarly, Hançerlioğulları (2020)²⁴, while investigating the effects of a six-week core and plyometric exercise program on balance in individual and team sport athletes, reported statistically notable enhancements in flexibility capacity ($p < 0.05$). The study also found that female participants showed greater improvements in flexibility compared to males, which was attributed to physiological differences between sexes²⁴.

The findings obtained in our study are consistent with previous literature indicating that plyometric training contributes to improvements in flexibility. Plyometric exercises enhance both intramuscular and intermuscular coordination, while also promoting

increases in strength and hypertrophy. It is believed that high-intensity jumping and bounding movements targeting the lower extremities strengthen the hip and leg muscles, thereby increasing range of motion and contributing to improved flexibility²⁵.

The Effects of Plyometric Training on Vertical Jump Performance

Cicioğlu et al. (1997)²⁶ conducted an 8-week study with 32 basketball players aged 14-15, applying plyometric training three times per week. The group that underwent plyometric training showed an increase of 8.31 cm in vertical jump performance, and analysis showed a statistically notable variation between the initial and final tests²⁶. Similarly, Fatouros (2000)²⁷ implemented a 12-week program involving 41 athletes divided into four groups (control, plyometric, weight training, and a combination of plyometric and weight training), with sessions conducted three times per week. In the plyometric group, vertical jump performance improved from 52.9±2.4 cm in the pre-test to 58.9±2.3 cm in the post-test, indicating a significant difference. Moreover, the combination group showed an even greater improvement, with a 9.2 cm increase in vertical jump height²⁷. Kaldırımçı et al. (2004)²⁸ investigated the effects of an 8-week plyometric training program, conducted twice a week, on 32 handball players. In the experimental group, the vertical jump score improved from 49.56±7.87 cm (pre-test) to 55.93±7.74 cm (post-test)²⁸. Chimera et al. (2004)²⁵, in a 6-week study conducted twice weekly, examined the effects of plyometric training on lower extremity muscle activation in female athletes. They observed positive changes in the quadriceps and hamstring muscles, which were associated with measurable advancements in lower-body explosive power²⁵. Martinez-Lopez et al. (2012)²⁹ studied 98 track and field athletes (both male and female) aged 17.91±1.42 years, applying plyometric training twice a week for eight weeks. Their findings demonstrated that plyometric exercises were effective in enhancing vertical jump performance, particularly in sprinting and hurdling disciplines²⁹.

When examining past and present research conducted on both individual and team sport athletes, it is evident that the plyometric training method has a positive effect on vertical jump performance one of the most critical parameters of athletic performance and that the findings of the present study are consistent with the existing literature. It is believed that the stretch-shortening cycle, executed through the optimal timing between eccentric and concentric muscle contractions during plyometric exercises, maximizes the development of muscular elasticity and conditioning, thereby contributing positively to vertical jump performance.

The Effects of Plyometric Training on Sprint Performance

Kurt (2011)³⁰ conducted a study with 32 students aged 15-16, all of whom played football in different sports clubs, and found that after eight weeks of plyometric training, the sprint performance of the experimental group improved significantly, with pre-test values of 4.37 s and post-test values of 4.12 s ($p<0.05$)³⁰. Similarly, Kotzamanidis (2006)³¹ reported significant improvements in sprint ability among prepubescent children, observing statistically significant differences ($p<0.05$) in the 0-30 m, 10-20 m, and 20-30 m intervals, though not in the 0-10 m segment³¹. Sayar (2018)¹⁴ found significant differences in pre- and post-test sprint performance following agility and plyometric training in 16-year-old athletes¹⁴, while Özgül (2019)³² reported similar findings among football players aged 17 to 19 after combined plyometric and core training³². Villarreal et al. (2012)³³, through the examination and quantitative synthesis of existing literature, confirmed that training with plyometric methods has demonstrated

a considerable effect on sprint performance³³. Likewise, Chaabene and Negra (2016)³⁴ observed significant improvements in both sprinting and jumping abilities following an eight-week plyometric training program designed to investigate the effects of training volume on performance³⁴. In another study, İlbak (2021)³⁵ showed that sprint performance benefitted from the application of electrical muscle stimulation alongside plyometric workouts by 21.40%, whereas exclusive plyometric training led to a 10.35% increase³⁵.

The variation in findings in relation to how plyometric training influences sprint performance may be attributed to several factors, including the multifaceted nature of sprinting itself (e.g., reaction time, movement speed, acceleration), differences in the sprint distances used in various studies, the age groups of participants, or technical aspects of the plyometric programs such as duration, intensity, and training load. Although the literature presents diverse results concerning the influence of plyometric training on sprint performance, many studies as well as based on the outcomes, it can be inferred that well-structured and systematically planned plyometric programs contribute to the enhancement of anaerobic strength and energy output, which in turn supports improvements in sprint ability.

The Effects of Plyometric Training on Agility Performance

Miller et al. (2006)³⁶ evaluated the performance benefits associated with a structured six-week plyometric training schedule on agility by administering both the Illinois and T-Test agility protocols, and found notable enhancements with statistical relevance in both test outcomes ($p < 0.05$)³⁶. Similarly, Thomas et al. (2009)³⁷ conducted a study on semi-professional participants consisting of football players aged approximately 17.3 ± 0.4 years and observed a notable improvement of 9% in agility performance between the pre-test and post-test results following six weeks of plyometric training³⁷. Vaczi et al. (2013)³⁸ examined the effects of a short-term, high-intensity six-week plyometric training program on power and agility in 24 male football players, reporting statistically significant differences between pre- and post-test agility scores ($p < 0.05$)³⁸. Dönmez (2019)³⁹, in a study on wushu athletes aged 18-23, found significant differences in both agility and reactive agility scores between pre- and post-tests after an eight-week plyometric training program. In the same study, a 3.5-second advantage in agility was observed in male athletes compared to females. This difference was attributed to sex-based physiological characteristics, particularly the greater overall muscle mass in males³⁹. Özbar et al. (2020)⁴⁰ conducted a twice-weekly plyometric training protocol over an eight-week period including 28 licensed football players aged 13-15, and reported statistically significant differences in pre- and post-test results for both sprint and agility parameters ($p < 0.05$)⁴⁰.

It is well known that futsal players require power to perform rapid reactions, changes of direction, and accelerations during defensive and offensive transitions in confined spaces. Given the physiological demands, energy metabolism, and mechanical characteristics of plyometric training particularly the explosive force generated through eccentric and concentric muscle contractions it is believed that such training effectively addresses these needs and enhances agility performance.

CONCLUSION

In conclusion, outcomes observed before and after the intervention indicate that the six-week plyometric training program had a positive impact on vertical jump, flexibility,

30-meter sprint, and agility performance parameters in futsal players. The consistency between the findings of this study and those of previous research further supports the notion that an appropriately planned and effectively executed plyometric exercise protocol, through the development of anaerobic power, can effectively enhance key performance components such as agility, flexibility, vertical jump, and sprinting ability which are essential for athletic success in young athletes.

Recommendations

- In plyometric training programs, factors such as intensity, frequency, duration, scope, number of repetitions, and sets should be carefully considered to minimize the risk of injury.
- Attention should be paid to variables such as age, gender, nutrition, fatigue, and timing when implementing plyometric exercises.
- As plyometric training involves explosive, anaerobic-based movements, it can be applied as a standalone session. However, if it is to be integrated into an existing training program, it should be performed at the beginning of the session.
- Since plyometric exercises involve sequential muscle contractions, the amortization phase within the stretch-shortening cycle should be carefully managed.
- Given that the movements rely heavily on explosive power derived from anaerobic capacity, correct usage of the ATP-CP energy system should be ensured.
- The surface and footwear used during plyometric training must be appropriate to ensure athlete safety and training efficiency.
- When applied to prepubescent children, plyometric training programs should be designed in a way that does not harm the muscle, bone, or joint structures, nor negatively affect growth and development.
- In this study, test measurements were conducted using indirect methods due to logistical constraints. Future studies are encouraged to utilize direct measurement techniques in laboratory settings for more precise and valid results.
- As this study focused solely on lower-body jumping movements due to the nature of futsal, future research may explore the effects of combined upper and lower extremity plyometric training.
- A review of existing studies, including this one, reveals that most research has been conducted on young athletes or those with lower levels of competitive experience. Therefore, it is recommended that future studies be carried out on older or more elite-level athletes to broaden the applicability of findings.

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