Akdeniz Spor Bilimleri Dergisi

Mediterranean Journal of Sport Science

MJSS

ISSN 2667-5463

# The Effect of Six-Week Plyometric Training on Reactive Strength Index and Anaerobic Capacity in U18 Male Football Players

Serkan KIZILCA[1], Muhammed Zahit KAHRAMAN[2], İsmail ÇELİK[3]

DOI: https://doi.org/10.38021asbid.1639298

ORIGINAL ARTICLE

[1]Bitlis Eren University, School of Physical Education and Sports, Bitlis/ Türkiye

[2]Bitlis Eren University, School of Physical Education and Sports, Bitlis/ Türkiye

3Muş Alparslan University, Social Sciences Institute, Muş/Türkiye

**Abstract**

This study aims to determine the effect of six-week plyometric training on the reactive strength index (RSI) and anaerobic capacity in U18 male football players. In the study, a pre-test post-test control group design, one of the experimental models of the quantitative research method, was used. A total of 18 male football players who voluntarily participated in the study were randomly assigned to the experimental group (n=9) and the control group (n=9). While the football players in the experimental group followed a plyometric training program three times a week for six weeks in addition to their regular football training, the football players in the control group only continued their regular football training during this period. Prior to the training program and at the end of the six-week period, the participants underwent assessments including the Reactive Strength Index (RSI) and the Wingate Anaerobic Power Test (WAnT). The normality of the data was determined using the Shapiro-Wilk test. For the analysis of normally distributed data, the Independent Sample T-Test was used for independent groups, while the Paired Sample T-Test was employed for dependent groups. According to the findings of the study, a significant difference in favor of the post-test was observed in the Reactive Strength Index (RSI) (t = -2.353; p = 0.046) and peak power (PP) (t = -3.418; p = 0.009) parameters of the experimental group football players. However, no significant difference was found in the mean power (MP) and fatigue index (FI) parameters. In conclusion, it was determined that the six-week plyometric training program applied to U18 male football players had positive effects on RSI and PP values.

***Keywords:*** Football, Reactive Strength Index, Anaerobic Power.

**Corresponding Author:**
Serkan KIZILCA
serkankizilca@hotmail.com

Received:
13.02.2025

Accepted:
17.03.2025

Online Publishing:
28.03.2025

# U18 Erkek Futbolcularda Altı Haftalık Pliometrik Antrenmanların Reaktif Kuvvet İndeksi ve Anaerobik Kapasiteye Etkisi

**Öz**

Bu çalışamanın amacı, U18 erkek futbolculara uygulanan altı haftalık pliometrik antrnmanların reaktif kuvvet indeksi (RSI) ve anaerobik kapasiteye etkisini belirlemektir. Araştırmada nicel araştırma yöntemi deneysel modellerinden ön test-son test kontrol gruplu desen kullanıldı. Araştırmaya gönüllü olarak katılan 18 erkek futbolcu seçkisiz olarak deney grubu (n=9) ve kontrol grubuna (n=9) ayrıldı. Deney grubundaki futbolculara düzenli futbol antrenmanına ek olarak altı hafta boyunca haftada 3 gün pliometrik antrenman programı uygulanırken kontrol grubundaki futbolculara bu sürede yalnızca düzenli futbol antrenmanı uygulandı. Araştırmaya katılan futbolculara antrenmanlar öncesi ve altı haftalık antrenmanlar sonunda RSI ve Wingate anerobik güç testi (WAnT) uygulandı. Verilerin normallik düzeyi Shapiro-Wilk testi ile belirlendi. Normal dağılım gösteren verilerin analizinde bağımsız gruplar için Independent Sample T Testi ve bağımlı gruplar için Paired Sample T Testi kullanıldı. Araştırmadan elde edilen bulgulara göre deney grubundaki futbolcuların RSI (t = -2,353; p = 0.046) ve zirve güç (PP) (t = -3,418; p = 0.009) parametrelerinde son testler lehine anlamlı bir fark tespit edillirken, ortalama güç (MP) ve yorgunluk indeksi (FI) paremetrelerinde anlamlı bir farklılık bulunmamıştır. Sonuç olarak, U18 erkek futbolculara uygulanan altı haftalık pliometrik antrenmanların RSI ve PP değerlerinde olumlu etkiler sağladığı belirlenmiştir.

***Anahtar kelimeler:*** Futbol, Reaktif Kuvvet İndeksi, Anaerobik Güç.

## Introduction

Football is acknowledged as the most significant sport of modern times. In this discipline, which requires the integration of technical and tactical skills with high performance to achieve success, there are approximately 260 million athletes worldwide. In competitions, the strength and endurance levels of athletes are key factors for success. Considering the increasing tempo of today's football, the average distance a football player runs in a 90-minute match is between 8-12 km. A significant proportion of these distances, approximately 80-90%, is performed at maximum heart rate, making strength and anaerobic capacity highly important (Tobakçal, 2019). Football is not only important and popular but also a sport in which achieving success is highly challenging for athletes. For football players to demonstrate good performance, having well-developed fundamental biomotor abilities, along with enhanced aerobic and anaerobic capacity, is highly important (Akgün, 1994). As in many other sports, increasing physical capacity and engaging in training that supports the development of fundamental motor skills are crucial in football. An effective training program should be tailored to the individual characteristics of the athlete while also incorporating the physical and physiological attributes required by the sport (Koç et al., 2000).

Sports have become a rapidly evolving sector with increasing participation worldwide. Parallel to this development, expectations for success in sports are continuously rising. Regardless of whether the discipline is an individual or a team sport, achieving success is becoming increasingly demanding. Coaches and athletes are constantly striving for better development. Considering the numerous training methods applied to enhance performance in light of advancements in sports science, plyometric training has become an increasingly widespread method due to its effectiveness in improving explosive power. Although plyometric exercises are generally known to contribute to lower extremity development, they also enhance upper extremity performance (Gençoğlu, 2008).

Plyometric training can be considered a training protocol that enhances motor skills in sports disciplines requiring jumping, changes of direction, and rapid sprinting movements demanding quickness (Matavulj et al., 2001; Diallo et al., 2001; Baktaal, 2008). By definition, plyometric training consists of exercises aimed at enhancing strength capacity and improving explosive muscle power, incorporating speed and strength exercises (Ateş et al., 2007). Plyometric training is a training method that includes movements such as jumping, hopping, leaping, and throwing, which develop strength and explosive power while enhancing athletic performance. This training method aims to maximize an athlete's explosive reaction time by inducing strong muscle contractions through rapid eccentric muscle contractions. In other words, plyometric exercises are movements that generate the highest level of muscle contraction in the shortest time (Bayraktar, 2006). The application of plyometric training involves throwing a ball or similar object for the upper extremities, while for the lower extremities, it includes movements such as jumping and leaping (Hazır, 1994). While plyometric exercises are engaging for athletes, they are also significant for coaches in terms of enriching training programs (Bompa, 2001). Although the overall tempo of football is predominantly aerobic, at various moments of the game, fast sprints, jumps, accelerations at different paces, and agility-based movements are frequently performed (Shephard, 1999). Therefore, an athlete's level of plyometric strength, speed, sudden accelerations at varying tempos, and endurance are crucial for success in football (Little and Williams, 2006). Plyometric training has been reported to be beneficial for young athletes when appropriate training guidelines are followed, as recommended by the Canadian Society for Exercise Physiology (CSEP) and the National Strength and Conditioning Association (NSCA) (Bedoya et al., 2015).

To enhance their performance, numerous adolescent soccer players engage in structured sports training programs during the winter months, when the frequency of soccer practices and games is reduced (Mujika et al., 2009).This ability to develop maximal force in a minimal bout of time is a requisite ability in most sports (Zatsiorsky et al., 2020). According to the National Strength and Conditioning Association (NSCA), preseason training tactics for soccer players should emphasize a combined training approach involving strength training, plyometric training, and various forms of sprint interval training (Turner and Stewart, 2014).

Similar to plyometric training, in exercises based on stretching and shortening, RSI is an auxiliary characteristic that determines the level of elastic energy storage in muscles and tendons, thereby influencing the efficiency of training (Flanagan et al., 2008). RSI (Reactive Strength Index) represents an individual's ability to effectively utilize the stretch-shortening cycle, which is commonly referred to as the capability of the muscle-tendon unit to generate a rapid and powerful concentric contraction immediately following a fast eccentric action (Komi, 2000; Jarvis et al., 2022). RSI defines the relationship between jump height and ground contact time (Kahraman & Özkan, 2023). It has been found that athletes with superior anaerobic performance possess fast-twitch muscle fibers, greater muscle volume, and a larger muscle mass (Staron et al., 2000).

In sports sciences, training methods aimed at enhancing athletic performance hold great significance. In particular, plyometric training is widely used to improve muscle strength, explosive power, and neuromuscular adaptation. This type of training enhances reactive strength capacity, thereby improving fundamental performance components such as jumping, speed, and endurance. Determining appropriate training models for developing athletes is a critical factor in maximizing their physical capacities. In this context, examining the effects of plyometric training on U18 athletes, assessing their performance improvements, and contributing to the literature has become a significant necessity. This study aims to determine the effects of a six-week plyometric training program on the

Reactive Strength Index (RSI) and aerobic capacities of U18 football players. Within the scope of the study, the development levels of athletes' explosive strength and endurance performance will be analyzed, and the findings obtained are expected to contribute to football training programs and the relevant literatüre.

## Materials and Methods

During the course of the present research, actions were carried out in accordance with the Guidelines for Scientific Research and Publication Ethics of Higher Education Institutions.

### *Participants*

The minimum sample size for this study was determined using G*Power software (version 3.1.9.7) (Faul et al., 2009). The analysis considered an α error probability of 0.05, and a statistical power of 0.80 (1-β error probability). In the power analysis, the number of people to be included was calculated as 16, based on a previous study (Meylan and Malatesta, 2009). A total of 18 participants were included in the study by evaluating the four-week training period. The study participants consists of eighteen U18 football players (9 experimental and 9 control) who play in the amateur local league of Muş province under the Turkish Football Federation and voluntarily participated in the study. This study was conducted during the season. The athletes participating in the study were informed about the training protocol and measurement tests to be applied. Before the sessions, the athletes were asked to warm up for a total of 15 minutes, consisting of 10 minutes of running and 5 minutes of stretching exercises. Detailed information about the study was provided to the athletes and their parents. A voluntary consent form was signed by the participating athletes, and a parental consent form was obtained from their guardians. Participants who had any chronic illness within the past year, had experienced musculoskeletal injuries, or required continuous medication were excluded from the study. Participants who had any chronic illness within the past year, had experienced musculoskeletal injuries, or required continuous medication were excluded from the study. All participants were instructed to adhere to their regular dietary habits and to avoid the use of any ergogenic aids or stimulants during the experimental period. Additionally, they were advised to refrain from engaging in intense physical activity and consuming caffeine for 24 hours before the measurements**.**

### *Study Model*

This study was designed as a quasi-experimental study with a pre-test and post-test control group, utilizing quantitative research methods.

### *Study Design*

This study employed an experimental method with a pre-test and post-test control group design, in which athletes were randomly assigned into two groups: an experimental group (n = 9) and a control group (n = 9). The experimental group participated in plyometric strength training three times a week in addition to their regular football training for six weeks. Meanwhile, the control group followed only their regular football training regimen. Before initiating the plyometric training program, both groups underwent assessments for height, body weight, RSI, and WAnT. After the six-week training period, the same tests were administered as post-tests to both groups.

### *Training Protocol*

The plyometric training protocol (Table 1) applied to the athletes was implemented three times per week for a duration of six weeks.

Table 1

Plyometric Training Protocol (Türkarslan & Deliceoğlu, 2024).

| Week | Plyometric Training | Sets | Reps | Rest | Training Duration |
|---|---|---|---|---|---|
| Weeks 1 & 2 | -Side to Side Hops<br>-Box Jump (15 cm)<br>-Drop Jump<br>-Hurdle Jump (15 cm)<br>-Squat Jump | 2 | 8 | 3 min | 35-40 min |
| Weeks 3 & 4 | -Side to Side Hops<br>-Box Jump (20 cm)<br>-Drop Jump<br>-Hurdle Jump (20 cm)<br>-Squat Jump | 2 | 12 | 3 min | 35-40 min |
| Weeks 5 & 6 | -Side to Side Hops<br>-Box Jump (30 cm)<br>-Drop Jump<br>-Hurdle Jump (30 cm)<br>-Squat Jump | 3 | 10 | 3 min | 35-40 min |

min: minute, cm: centimeter.

### *Data Collection Tools*

#### *Height Measurement*

The height of the participants was measured using a stadiometer (SECA, Germany) with a precision of 0.01 meters (m).

#### *Body Weight Measurement*

Body weight (BW) was measured using an electronic scale (Tanita BC-418 MA, Japan) with a precision of 0.1 kilograms (kg).

*Reactive Strength Index (RSI) Measurement*

The electronic jump mat (Fusion Sport Smart Jump, Australia) was used to determine RSI. All data were reset before the athlete stepped onto the mat. The test began with each athlete jumping onto the mat from an external position with their hands placed on their hips. For RSI measurement, athletes performed a total of 11 consecutive jumps. Since the first jump served as a countermovement jump (CMJ) to initiate the subsequent 10 jumps, it was excluded from the evaluation. Vertical Ground Reaction Force (GRF) data were collected at a sampling rate of 1000 Hz for a duration of 15 seconds. Athletes were instructed to jump as high as possible while minimizing ground contact time. Among the 10 recorded jumps, the average of the highest five values was used to calculate RSI. The test was performed twice, with 90 seconds of rest between trials, and the highest recorded values were considered (Stratford et al., 2020). The RSI variable was calculated using the equation RSI = Jump Height (mm) / Ground Contact Time (ms) (Flanagan and Comyns, 2008).

*Wingate Anaerobic Power Test (WAnT)*

To determine anaerobic power parameters, the (WAnT) was administered to the athletes. The test was conducted on a lower-extremity cycle ergometer (Monark 894E, Monark, Varberg, Sweden). WAnT consisted of pedaling at maximum speed for 30 seconds on the ergometer while applying a resistance of 0.075 kp•kg−1 per kilogram of body weight (Ramírez-Vélez et al., 2016). The athletes' age, body weight, and height were recorded in the ergometer’s software via the connected computer. The resistance to be applied to each participant was determined by the software and placed in the ergometer’s weight basket. The saddle height was adjusted according to the athlete's height, and their feet were secured to the pedals using clips. Following a five-minute free warm-up period, athletes performed a three-minute unloaded pedaling exercise at a cadence not exceeding 50–60 revolutions per minute (rpm). Once the predetermined resistance was placed in the weight basket and the athlete felt ready, the test began. As the athlete reached maximum pedaling speed, the weight was automatically released, transmitting resistance from the load to the pedals. At this stage, participants were instructed to maintain their pedaling speed for 30 seconds with maximal effort. Throughout the WAnT, athletes were verbally encouraged. After completing the test, Peak Power (PP) and Mean Power (MP) anaerobic power parameters were determined by the ergometer’s software. The Fatigue Index was calculated using the equation: Fatigue Index = [(Peak Power - Minimum Power) / (Peak Power)] x 100 (Zagatto et al., 2009).

***Data Analysis***

The SPSS statistical software package was used for data analysis. The normality of the data distribution was determined using the Shapiro-Wilk test. Parametric tests were applied to data that followed a normal distribution. For comparisons between two independent groups, the Independent Samples T-test was used, whereas for within-group comparisons, the Paired Samples T-test was applied. Time-dependent percentage changes within groups (%Δ) were calculated using the equation: %Δ = [(Post-test - Pre-test) / Pre-test] × 100.

### *Ethics of Research*

Prior to the commencement of the study, ethical approval was obtained from the Scientific Research and Publication Ethics Committee of Muş Alparslan University (Date: April 15 2024; Meeting No. 6; Decision No. 27).

## Results

Descriptive statistical results regarding the general characteristics of the U18 football players participating in the study are presented in Table 2. The comparison of the baseline values of RSI, PP, MP, and FI between the experimental and control groups is presented in Table 3.

Table 2

General Characteristics of the Athletes.

| **General Characteristics** | **Experimental Group (n=9)** | **Control Group (n=9)** |
|---|---|---|
| | **Mean ± SD** | **Mean ± SD** |
| Age (years) | 19.78 ± 2.59 | 19.11 ± 0.93 |
| Height (cm) | 180.11 ± 7.61 | 181.00 ± 6.44 |
| Body Weight (kg) | 68.89 ± 8.28 | 69.62 ± 8.90 |

n: number of participants, SD: standard deviation.

Table 3

Comparison of Pre-Test Values Between Groups

| **Tests** | **Experimental Group (n=9)** | **Control Group (n=9)** | **t** | ***p*** |
|---|---|---|---|---|
| | **Mean ± SD** | **Mean ± SD** | | |
| RSI (mm/ms) | 1.67 ± 0.36 | 1.63 ± 0.17 | .307 | .763 |
| Peak Power (W/kg) | 11.50 ± 2.00 | 12.11 ± 2.01 | -.645 | .528 |
| Mean Power (W/kg) | 8.27 ± 0.85 | 8.60 ± 0.98 | -.750 | .464 |
| Fatigue Index (%) | 59.78 ± 12.37 | 54.58 ± 5.73 | 1.144 | .270 |

n: number of participants, SD: standard deviation.

According to the findings in the table, no significant differences were found between the pre-test values of the groups. These results indicate that the groups were statistically similar.

Table 4

Comparison of Pre-Test and Post-Test Values in the Experimental Group

| **Tests** | **Pre-Test (n=9)** | **Post-Test (n=9)** | **%Δ** | **t** | ***p*** |
|---|---|---|---|---|---|
| | **Mean ± SD** | **Mean ± SD** | | | |

| | | | | | |
|---|---|---|---|---|---|
| RSI (mm/ms) | 1,67 ± 0,36 | 1,84 ± 0,40 | 9,35↑ | -2,353 | ,046 |
| Peak Power (W/kg) | 11,50 ± 2,00 | 13,16 ± 1,26 | 12,62↑ | -3,418 | ,009 |
| Mean Power (W/kg) | 8,27 ± 0,85 | 8,73 ± 0,17 | 5,27↑ | -1,737 | ,121 |
| Fatigue Index (%) | 59,78 ± 12,37 | 63,21 ± 9,19 | 5,43↑ | -0,822 | ,435 |

n: number of participants, SD: standard deviation, %Δ: percentage change.

When the pre-test and post-test values of the football players in the experimental group were compared, a significant difference was found in favor of the post-test results for the RSI (t = -2.353; p = 0.046) and PP (t = -3.418; p = 0.009) parameters. However, no significant difference was observed in the MP and FI parameters (Table 4).

Table 5

Comparison of Pre-Test and Post-Test Values in the Control Group

| | **Pre-Test (n=9)** | **Post-Test (n=9)** | | | |
|---|---|---|---|---|---|
| **Tests** | **Mean ± SD** | **Mean ± SD** | **%Δ** | **t** | ***p*** |
| RSI (mm/ms) | 1.63 ± 0.17 | 1.60 ± 0.30 | -1.89↓ | .441 | .671 |
| Peak Power (W/kg) | 12.11 ± 2.01 | 12.78 ± 1.64 | 5.21↑ | -1.580 | .153 |
| Mean Power (W/kg) | 8.60 ± 0.98 | 8.60 ± 0.57 | 0.04↑ | -.017 | .987 |
| Fatigue Index (%) | 54.58 ± 5.73 | 62.51 ± 14.69 | 12.69↑ | -1.290 | .233 |

n: number of participants, SD: standard deviation, %Δ: percentage change.

In the control group, no significant differences were found in RSI, PP, MP, and FI parameters when comparing the pre-test and post-test values (Table 5).

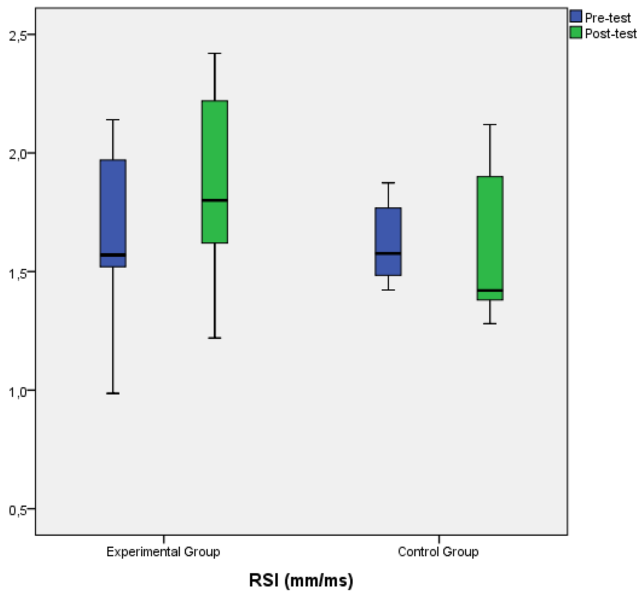


Figure 1. Comparison of Pre-Test and Post-Test RSI Values in the Experimental and Control Groups

The post-test RSI values in the experimental group were higher than the pre-test values ($p < 0.05$). In the control group, no significant difference was found between pre-test and post-test values ($p > 0.05$), (Figure 1).

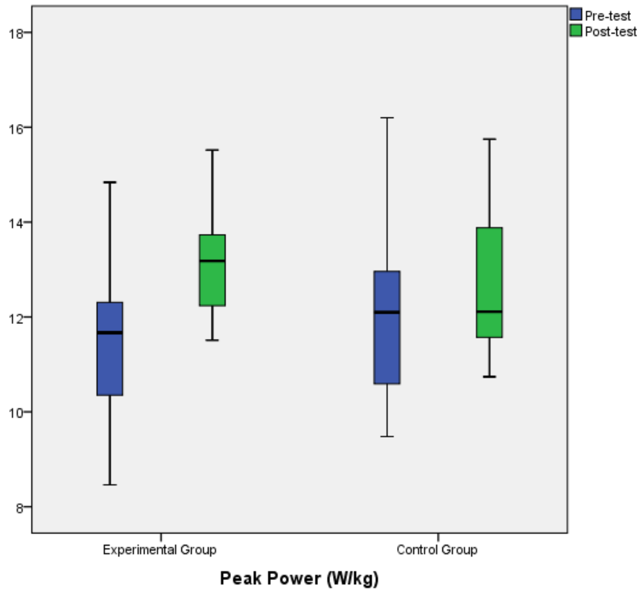


Figure 2. Comparison of Pre-Test and Post-Test Peak Power Values in the Experimental and Control Groups

The post-test peak power values in the experimental group were higher than the pre-test values ($p < 0.05$). In the control group, no significant difference was found between pre-test and post-test values ($p > 0.05$), (Figure 1).

## Discussion

In this study, the effects of a six-week plyometric training program on the RSI and anaerobic capacities of U18 football players were examined. When comparing the pre-test and post-test results, significant improvements and positive differences were observed in RSI and anaerobic peak power (PP) values in the experimental group. However, no statistically significant differences were found in the control group.

A review of the literature reveals that Türkaslan and Deliceoğlu (2024) examined the effects of plyometric training on agility, jump performance, and speed in young football players. Their study found that plyometric training had a positive impact on anaerobic power. The results of their study support the findings of our study. Furthermore, numerous studies in the literature align with our findings. Lloyd et al. (2012) examined the effects of a 4-week plyometric training program on leg strength and the Reactive Strength Index in football players, and the study found significant improvements in both leg strength and the Reactive Strength Index. Feng et al. (2024) conducted a study on gymnasts with 54 female participants and found that plyometric training was more effective than traditional training in improving CMJ and RSI. Grieco et al. (2012) investigated the effects of plyometric training on strength and peak power (PP) levels in female football players. Their study concluded that plyometric training enhanced both strength levels and PP. Singh et al. (2024) examined the effects of plyometric training on the physiological parameters of football players and found that participants in the experimental group showed significant improvements in physiological parameters compared to the control group. Bianchi et al. (2018) applied both low-volume and high-volume plyometric training to elite young male football players and found significant improvements in speed, jump, and change of direction tests. Kobal et al. (2017) investigated the effects of different combinations of plyometric training on the physical performance of elite young football players and found improvements in CMJ performance and sprint performance. Meylan and Malatesta (2009) examined the impact of plyometric training in young football players and found that incorporating a plyometric program alongside regular football training improved explosive movements and reactive strength more effectively than traditional football training alone Váczi et al. (2013) examined the effects of an in-season plyometric training program on power, agility, and knee extensor strength in football players. Their study found that plyometric training led to significant improvements in lower extremity power and maximal knee extensor strength. Ramirez-Campillo et al. (2018b) investigated the effects of plyometric training on RSI in a study involving 24 football players and reported notable improvements in both RSI and anaerobic power. Ebben and Petushek (2010) conducted a study with 23 female athletes, implementing a plyometric training program. Their findings indicated improvements in RSI and explosive power. Similarly, Chelly et al. (2010) concluded that an eight-week lower-extremity plyometric training program had a positive impact on strength, speed, and jumping ability (squat jump, countermovement jump) in young football players. Kutlu et al. (2001) incorporated plyometric training twice a week in addition to regular training in their study on football players. As a result, they observed significant improvements in anaerobic power, leg strength, and jump performance. Additionally, Dallas et al. (2020) implemented a four-week plyometric training program for 24 athletes and found a significant increase in RSI and anaerobic power-based leg strength in the post-test results.

Plyometric training is consistently an effective method for strength development (De Villarreal et al., 2010). Due to its ability to enhance overall strength and explosive anaerobic power, plyometric training has become a widely used method across various sports disciplines (Miller et al., 2006). Sağıroğlu (2008) found that an eight-week plyometric training program positively influenced anaerobic power, vertical jump performance, anaerobic capacity, and strength in athletes. Similarly, Luebbers et al. (2003) examined the effects of two different plyometric training protocols (4 weeks and 7 weeks) on anaerobic power and observed improvements in both groups. Plyometric training protocols aim to significantly enhance strength and generally lead to notable improvements in RSI and PP (Ramirez-Campillo et al., 2018a; Ramirez-Campillo et al., 2020). Adıgüzel and Günay (2016) reported that an eight-week plyometric training program applied to basketball players aged 15–18 resulted in improvements in PP and reactive strength-based jumps. Likewise, Zhang et al. (2024) found that a plyometric training program for basketball players led to increases in maximal strength and PP in elite male university basketball players. The findings from these studies strongly support the results of our study.

## Conclusion

In conclusion, it was determined that a six-week plyometric training program, implemented in addition to routine football training, led to statistically significant positive differences in RSI and PP values among U18 male football players. Based on this finding, incorporating plyometric training into preseason preparation and in-season training programs may enhance RSI and anaerobic PP values, thereby positively contributing to the athletic performance of football players.

## Ethics Committee Permission Information

Ethics review board: Muş Alparslan University- Scientific Research And Publication Ethics Committee

Date of ethical approval document: 15.04.2024

Issue number of the ethical approval document: 6/27

## Authors' contributions

In this study, the introduction, methodology, findings, discussion, and conclusion sections were prepared by the first author. The statistical analyses and interpretation of the findings were conducted by the second author. The data collection process was carried out by the third author.

## Conflict of interest

The authors declare no conflict of interest

## References


Adigüzel, N. S., & Günay, M. (2016). The effect of eight weeks plyometric training on anaerobic power, counter movement jumping and isokinetic strength in 15-18 years basketball players. *International Journal of Environmental and Science Education*, *11*(10), 3241-3250.

Akgün, N. (1994). Egzersiz fizyolojisi. Ege Üniversitesi Basımevi

Ateş, M., Demir, M., & Ateşoğlu, U. (2007). Pliometrik Antrenmanın 16-18 Yaş Grubu Erkek Futbolcuların Bazı Fiziksel ve Fizyolojik Parametreleri Üzerine Etkisi. *Beden Eğitimi ve Spor Bilimleri Dergisi*, *1*(1), 1-12. https://doi.org/10.1501/Sporm_0000000123

Baktaal, D. G. (2008). *16-22 yaş bayan voleybolcularda pliometrik çalışmaların dikey sıçrama üzerine etkilerinin belirlenmesi*. Unpublished Master's Thesis, Çukurova University, Institute of Health Sciences, Adana.

Bayraktar I. (2006). Farklı spor branşlarinda pliometrik güç gelişiminin anahtari, Ata Ofset Matbaacılık.

Bedoya, A. A., Miltenberger, M. R., & Lopez, R. M. (2015). Plyometric training effects on athletic performance in youth soccer athletes: a systematic review. *The Journal of Strength & Conditioning Research*, *29*(8), 2351-2360. https://doi.org/10.1519/JSC.0000000000000877

Bianchi, M., Coratella, G., Dello Iacono, A., & Beato, M. (2019). Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint, and change of direction abilities of elite youth football players. *Journal of Sports Medicine and Physical Fitness*, *58*(8), 1223-1229. https://doi.org/10.23736/S0022-4707.18.08804-7

Bompa T. O. (2001). Sporda çabuk kuvvet antrenmanı. Bağırgan Yayımevi. 35, 46- 47.

Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *The Journal of Strength & Conditioning Research*, *24*(10), 2670-2676. https://doi.org/10.1519/JSC.0b013e3181e2728f

Dallas, G. C., Pappas, P., Ntallas, C. G., Paradisis, G. P., & Exell, T. A. (2020). The effect of four weeks of plyometric training on reactive strength index and leg stiffness is sport dependent. *Journal of Sports Medicine and Physical Fitness*, *60*(7), 979-984. https://doi.org/10.23736/S0022-4707.20.10384-0

De Villarreal, E. S. S., Requena, B., & Newton, R. U. (2010). Does plyometric training improve strength performance? A meta-analysis. *Journal of Science and Medicine in Sport*, *13*(5), 513-522. https://doi.org/10.1016/j.jsams.2009.08.005

Diallo. Dore E, Duche P., & Van P.E. (2001). Effects of plyometric training followed by a reduced training programmeon physical performancein prepubescent soccer players, *Journal of Sports Medicine and Physical Fitness*, *41*(3), 342-348.

Ebben, W. P., & Petushek, E. J. (2010). Using the reactive strength index modified to evaluate plyometric performance. *The Journal of Strength & Conditioning Research*, *24*(8), 1983-1987. https://doi.org/10.1519/JSC.0b013e3181e72466

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Feng, D., Yang, W., & Li, L. (2024). Countermovement jump and reactive strength index of artistic gymnasts improve more with cluster-based plyometric training than with traditional methods. *Scientific Reports*, *14*(1), 24700. https://doi.org/10.1038/s41598-024-76150-1

Flanagan, E. P., & Comyns, T. M. (2008). The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. *Strength & Conditioning Journal*, *30*(5), 32-38. https://doi.org/10.1519/SSC.0b013e318187e25b

Flanagan, E. P., Ebben, W. P., & Jensen, R. L. (2008). Reliability of the reactive strength index and time to stabilization during depth jumps. *Journal of Strength and Conditioning Research*, *22*(5), 1677-1682. https://doi.org/10.1519/JSC.0b013e318182034b

Gençoğlu, C. (2008). *Hentbolcularda Üst Ekstremiteye Uygulanan Pliyometrik Egzersizin Atış Hızı ve İzokinetik Kas Kuvvetine Etkisi*. Unpublished Master's Thesis, Dokuz Eylul University, Institute of Health Sciences, İzmir.

Grieco, C. R., Cortes, N., Greska, E. K., Lucci, S., & Onate, J. A. (2012). Effects of a combined resistance-plyometric training program on muscular strength, running economy, and V [combining dot above] O2peak in division I female soccer players. *The Journal of Strength & Conditioning Research*, *26*(9), 2570-2576. https://doi.org/10.1519/JSC.0b013e31823db1cf

Hazır, T. (1994). *Eksantrik ve Konsantrik Kas Kasılmasında Oksijen Tüketimi*. Unpublished Master of Science Thesis. Hacettepe University, Institute of Health Sciences. Ankara.

Jarvis, P., Turner, A., Read, P., & Bishop, C. (2022). Reactive strength index and its associations with measures of physical and sports performance: A systematic review with meta-analysis. *Sports Medicine*, *52*(2), 301-330. https://doi.org/10.1007/s40279-021-01566-y

Kahraman, M. Z., & Özkan, Z. (2023). The relationship between reactive strength index and agility in young male volleyball and basketball players. *Yalova Üniversitesi Spor Bilimleri Dergisi*, *2*(1), 100-112. https://dergipark.org.tr/en/pub/yalovaspor/issue/76342/1262770

Kobal, R., Loturco, I., Barroso, R., Gil, S., Cuniyochi, R., Ugrinowitsch, C., ... & Tricoli, V. (2017). Effects of different combinations of strength, power, and plyometric training on the physical performance of elite young soccer players. *The Journal of Strength & Conditioning Research*, *31*(6), 1468-1476. https://doi.org/10.1519/JSC.0000000000001609

Koç, H., Gökdemir, K., & Kılınç, F. (2000.) Sezon arasinda yapilan antrenmanlarin kütahyaspor futbolcularinin bazi fiziksel ve fizyolojik parametrelerine etkisi, Gazi Üni. Beden Eğt. ve Spor Bilimleri 1. Kongresi, (s.122-128). Ankara, Türkiye.

Komi, P. V. (2000). Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. *Journal of Biomechanics*, *33*(10), 1197-1206. https://doi.org/10.1016/S0021-9290(00)00064-6

Kutlu, M., Gür, E., Karahüseylnoğlu, M. F., & Kamanlı, A. (2001). Plyometrik antrenmanin genç futbolcularin anaerobik güçlerine etkisi. *Gazi Beden Eğitimi ve Spor Bilimleri Dergisi*, *6*(4), 37-43.

Little, T., & Williams, A. G. (2006). Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *The Journal of Strength & Conditioning Research*, *20*(1), 203-307. doi: 10.1519/R-16944.1.

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2012). The effects of 4-weeks of plyometric training on reactive strength index and leg stiffness in male youths. *The Journal of Strength & Conditioning Research*, *26*(10), 2812-2819. https://doi.org/10.1519/JSC.0b013e318242d2ec

Luebbers, P. E., Potteiger, J. A., Hulver, M. W., Thyfault, J. P., Carper, M. J., & Lockwood, R. H. (2003). Effects of plyometric training and recovery on vertical jump performance and anaerobic power. *The Journal of Strength & Conditioning Research*, *17*(4), 704-709. https://doi.org/10.1519/00124278-200311000-00013

Matavulj, D., Kukolj, M., Ugarkovic, D., Tihanyi, J., & Jaric, S. (2001). Effects of plyometric training on jumping performance in junior basketball players. *Journal of Sports Medicine and Physical Fitness*, *41*(2), 234-240.

Meylan, C., & Malatesta, D. (2009). Effects of in-season plyometric training within soccer practice on explosive actions of young players. *The Journal of Strength & Conditioning Research*, *23*(9), 2605-2613. https://doi.org/10.1519/JSC.0b013e3181b1f330

Mujika, I., Santisteban, J., & Castagna, C. (2009). In-season effect of short-term sprint and power training programs on elite junior soccer players. *The Journal of Strength & Conditioning Research*, *23*(9), 2581-2587. https://doi.org/10.1519/JSC.0b013e3181bc1aac

Ramirez-Campillo, R., Álvarez, C., García-Hermoso, A., Ramírez-Vélez, R., Gentil, P., Asadi, A., & Izquierdo, M. (2018b). Methodological characteristics and future directions for plyometric jump training research: a scoping review. *Sports Medicine*, *48*, 1059-1081. https://doi.org/10.1007/s40279-018-0870-z

Ramirez-Campillo, R., Alvarez, C., García-Pinillos, F., Sanchez-Sanchez, J., Yanci, J., & Castillo, D. (2018a). Optimal reactive strength index: Is it an accurate variable to optimize plyometric training effects on measures of physical fitness in young soccer players? *The Journal of Strength & Conditioning Research*, *32*(4), 885-893. https://doi.org/10.1519/JSC.0000000000002467

Ramirez-Campillo, R., Moran, J., Chaabene, H., Granacher, U., Behm, D. G., García-Hermoso, A., & Izquierdo, M. (2020). Methodological characteristics and future directions for plyometric jump training research: A scoping review update. *Scandinavian Journal of Medicine & Science in Sports*, *30*(6), 983-997. https://doi.org/10.1111/sms.13633

Ramírez-Vélez, R., López-Albán, C. A., La Rotta-Villamizar, D. R., Romero-García, J. A., Alonso-Martinez, A. M., &Izquierdo, M. (2016). Wingate anaerobic test percentile norms in colombian healthy adults. *The Journal of Strength & Conditioning Research*, *30*(1), 217-225. https://doi.org/10.1519/JSC.0000000000001054

Sağiroğlu, İ. (2008). Genç *Basketbolcularda Pliyometrik Antrenmanların Anaerobik Performans ve Dikey Sıçrama Yüksekliğine Etkisi*. Unpublished Master's thesis, Institute of Health Sciences, Dokuz Eylul University, İzmir.

Shephard R.J. (1999). Biology and medicine of soccer, an update. *Journal of Sports Sciences*, *17*, 757-786. https://doi.org/10.1080/026404199365498

Singh, L. S., Singh, W. J., Azeem, K., Meitei, N. M., & Mola, D. W. (2024). Concept of plyometric training and its effect on physiological parameters of football players. *Physical Education Theory and Methodology*, *24*(4), 609-618. https://doi.org/10.17309/tmfv.2024.4.13

Staron, R. S., Hagerman, F. C., Hikida, R. S., Murray, T. F., Hostler, D. P., & Crill, M. T. (2000). Fiber type composition of the vastus lateralis muscle of young men and women. *The Journal of Histochemistry and Cytochemistry*, *48*(5), 623-629. https://doi.org/10.1177/002215540004800506

Stratford, C., Dos'Santos, T., and McMahon, J. J. (2020). Comparing drop jumps with 10/5 repeated jumps to measure reactive strength index. *Prof. Strength Cond*, *57*, 23-28.

Tobakçal, F. (2019). *Genç Elit Futbolcularda Yüksek Yoğunluklu Aralikli Antrenmanin Performansa ve Kognitif Fonksiyona Etkisi.* Master's thesis, Selçuk Üniversitesi, Sağlık Bilimleri Enstitüsü, Konya.

Turner, A. N., & Stewart, P. F. (2014). Strength and conditioning for soccer players. *Strength & Conditioning Journal*, *36*(4), 1-13. https://doi.org/10.1519/SSC.0000000000000054

Türkarslan, B., & Deliceoglu, G. (2024). The effect of plyometric training program on agility, jumping, and speed performance in young soccer players. *Pedagogy of Physical Culture and Sports*, *28*(2), 116-123. https://doi.org/10.15561/26649837.2024.0205

Váczi, M., Tollár, J., Meszler, B., Juhász, I., &Karsai, I. (2013). Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. *Journal of Human Kinetics*, *36*, 17. https://doi.org/10.2478/hukin-2013-0002

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. *The Journal of Strength & Conditioning Research*, *23*(6), 1820-1827. https://doi.org/10.1519/JSC.0b013e3181b3df32

Zatsiorsky, V. M., Kraemer, W. J., & Fry, A. C. (2020). Science and practice of strength training. Human kinetics.

Zhang, W., Chen, X., Xu, K., Xie, H., Chen, J., Zhu, Z., & Sun, J. (2024). The potential of a targeted unilateral compound training program to reduce lower limb strength asymmetry and increase performance: a proof-of-concept in basketball. *Frontiers in Physiology*, *15*, 1361719. https://doi.org/10.3389/fphys.2024.1361719