European Journal of Physical Education and Sport Science
ISSN: 2501 - 1235
ISSN-L: 2501 - 1235
Available on-line at: www.oapub.org/edu

DOI: 10.46827/ejpe.v11i7.5684 Volume 11 | Issue 7 | 2024

INVESTIGATION OF THE EFFECTS OF PLYOMETRIC EXERCISES ON AGILITY, BALANCE, FLEXIBILITY AND DEPTH OF GROUND STROKES İN TENNIS PLAYERS AGED BETWEEN 9-12

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Abstract:
This study aimed to investigate the effects of plyometric training on agility, balance, flexibility, and groundstroke depth in 9-12-year-old tennis players. A randomized controlled experimental design was employed in this cross-sectional study. Sixteen tennis players aged 9-12 participated in the study. Eight participants formed the control group and continued with their regular tennis training, while the other eight formed the experimental group and additionally performed plyometric training three times a week for four weeks. Pro-agility test, flamingo balance test, sit-and-reach test, and ITN groundstroke depth test were administered to all participants before and after the study. Paired samples t-tests revealed significant differences between pre- and post-test scores in all parameters except right-side flexibility for the experimental group (p<0.05). No significant differences were found between pre- and post-test scores in the control group (p>0.05). Independent samples t-tests comparing the differences between pre- and post-test scores of the two groups showed significant differences in favor of the experimental group in all parameters except right and left side flexibility and agility (p<0.05).

Keywords: plyometric training, court tennis, kids, ITN, balance, agility, flexibility

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1. Introduction

Tennis is a demanding sport that requires both physical and mental agility. Players use rackets to hit a ball back and forth over a net, aiming to land it within designated areas on the opponent's side of the court. To achieve this, players must skillfully manipulate the ball's speed, direction, and trajectory, employing both attacking and defensive strategies (Gencel, 2021).

Despite being a sport played with only a racket and a ball, tennis is a highly complex activity that requires nearly all components of physical fitness. Rapid changes in direction, sudden accelerations, plyometric movements, and long rallies demanding endurance are key characteristics that set tennis apart from other sports. Athletes need specially designed training programs to meet these physical demands. These programs should include exercises targeting specific physical attributes such as balance, endurance, agility, and coordination, as well as exercises designed for the sport's specific movements (Özcan, 2011).

Tennis is a high-intensity interval training sport that demands not only balance and strength but also efficient utilization of the anaerobic energy system. Throughout a match, players continuously transition between varying intensities of movement. This necessitates the rapid and effective activation of the ATP and CP energy systems. To maintain strength and endurance throughout a match, tennis players must incorporate exercises into their training programs that develop their anaerobic capacity (Kilit ve Arslan, 2017).

Regular training has a positive impact on the physical fitness parameters of tennis players. The benefits of both on-court and off-court training can be seen. However, it can be assumed that on-court training has a more positive impact on the athletic performance of children as it is thought to improve skill parameters such as reaction time (Martinez-Gallegoi R, vd, 2018).

Tennis players not only need to be physically strong but also require the ability to execute explosive, short-duration movements on the court, combined with strategic and effective strokes. This necessitates a high level of both physical and mental performance (Elliott BC, Reid M, Crespo M, 2018).

For these reasons, tennis players must possess versatile movement skills and well-developed dynamic qualities during competitions. Athletes need to be able to generate explosive force in a very short time. Actions such as high-speed running, changing direction, or hitting to any point on the court are significant factors that directly affect a tennis player's match performance (Brughelli M, 2008).

Plyometric training is a training method based on the principle of muscles storing potential energy during the eccentric phase by stretching and then converting this energy into explosive force during the concentric phase. Plyometric exercises help athletes improve performance characteristics such as strength, speed, agility, and coordination, thereby enhancing their success in their respective sports. Therefore, they can be effectively used in all sports that require explosive power and speed (such as basketball, volleyball, high jump, short-distance running) and in sports that aim to impart maximum speed to an object (such as baseball, hockey, golf, tennis, table tennis) (Bompa 2001).

In sports that prioritize explosive movements, such as tennis, each stroke involves a mechanism known as the stretch-shortening cycle. In this cycle, the muscle is first stretched (eccentric phase) and then rapidly shortened (concentric phase). Plyometric training aims to optimize this cycle, thereby increasing an athlete's explosive power and speed. Especially when conducted during adolescence and young adulthood, plyometric exercises can positively impact an athlete's long-term performance by supporting the development of the musculoskeletal system. For these reasons, it can be used as a training method (Cormie P, 2010).

Plyometric exercises enhance children's strength and shock absorption capacity, thereby improving sports performance and reducing the risk of injury. Therefore, it is essential to include plyometric exercises in children's training programs. Plyometric training induces a heightened excitability of a greater muscle mass, resulting in increased motor unit recruitment and synchronization. The concomitant increase in neural activation rate accelerates force production, facilitating the conversion of muscular strength into explosive power.

In essence, plyometric exercises strengthen the neuromuscular connection of the nervous system, optimizing the stretch-shortening cycle. Through this mechanism, muscles can generate maximum force in a shorter time, increasing an athlete's explosive power (Fernandez J, 2014).

Plyometric training significantly enhances athletes' ability to generate explosive force by optimizing the stretch-shortening cycle of the musculoskeletal system. This fosters a synergistic interaction between performance components such as speed, agility, and strength. Consequently, the systematic implementation of plyometric training in sports that demand strength and speed is crucial for optimizing athletes' performance (Bompa, 2001).

The findings suggest that plyometric training can enhance the physical performance of tennis players. Based on these results, it is believed that incorporating plyometric training into tennis training programs can positively influence players' overall performance.

A literature review has revealed a limited number of studies on the effects of plyometric training in 9-12-year-old tennis players. The aim of this study is to fill this gap in knowledge regarding the use of plyometric training in this age group and to provide a foundation for future research. The goal is to achieve a more comprehensive understanding of the effectiveness of plyometric training in tennis youth development.

2. Materials and Methods

2.1. Research Model

A randomized controlled trial (RCT) design was employed in our cross-sectional study. Sixteen tennis players aged 9-12 from Yeşilkent Şehit Ömer Polat Middle School in

Gaziantep participated in our study. Eight participants comprised the control group and continued with their regular tennis training, while the remaining eight participants formed the experimental group and additionally performed plyometric exercises three times a week for four weeks. Before and immediately after the study, participants underwent the pro-agility test, flamingo balance test, sit-and-reach test, and ITN ground reaction force depth test. The necessary approvals for the study were obtained from the Ethics Committee of Gaziantep University, Faculty of Health and Sports Sciences.

A portion of the study group was enrolled in a plyometric exercise training program for four weeks, three times per week. Following a warm-up at the beginning of each training session, the training sessions lasted approximately 40 minutes. Participants were instructed to perform plyometric exercises exclusively during the designated training periods. Athletes in the experimental group participated in tennis training after completing their plyometric workouts, while the control group continued with tennis training only.

2.2. Data Collection Tools

2.2.1 Pro Agility Agility Test

The starting position of the agility test is defined by marker cones placed 4.57 meters to the left and right of the starting line. The athlete stands in front of the starting gate located on the starting line. When ready, they touch the right cone, cross the starting line, and then touch the left cone to complete the test. It is important for the athlete to keep their arms out to the sides and their body upright during this process (Jakopsen M.D, 2011).

2.2.2 Flamingo Balance Test

a. Starting Position

The athlete stands on the balance board with their right foot. They lift their left leg and touch their knee to their chest with their left hand, achieving maximum flexion. The athlete is instructed to fix their gaze on a point 5 meters away.

b. Test Commencement

The instructor holds the athlete's hand and gives the start command, simultaneously releasing their hand. The stopwatch starts.

c. Error Conditions

- The test is considered failed if the athlete drops their leg or any part of their body touches the ground.
- If the athlete uses their other hand to hold onto a barrier or touches the instructor, it is considered an error.

d. Time and Scoring

- One second is deducted for each error.

- If the athlete makes 15 errors within the first 30 seconds, the test is stopped and a score of zero is given.
- The test lasts a total of 2 minutes, and each error is counted as one point.
- The test is repeated three times, and the average number of errors is calculated.

e. Purpose and Evaluation

- Balance and Stability: The test assesses the athlete's ability to stand on one leg, maintain balance, and coordinate eye-foot movements.
- Muscle Strength and Coordination: Factors such as holding the knee in a flexed position and activating the abdominal muscles are also evaluated.
- Concentration: The athlete's ability to maintain focus on a fixed point is tested.

f. Interpreting Results

- Low Error Count: Indicates better balance and stability.
- High Error Count: May indicate balance and coordination problems, muscle weakness, or lack of attention (Tamer, 2000)

g. Sit-Reach Test

The sit-and-reach test is a standardized method used to measure the flexibility of the hamstrings and lower back in athletes. During the test, the athlete sits in a specific position and reaches forward as far as possible without bending their knees, holding the final position for 1-2 seconds. The maximum distance reached is measured. The test is repeated twice, and the highest score is recorded. This measurement provides objective data on the athlete's flexibility level (Tamer, 2000).

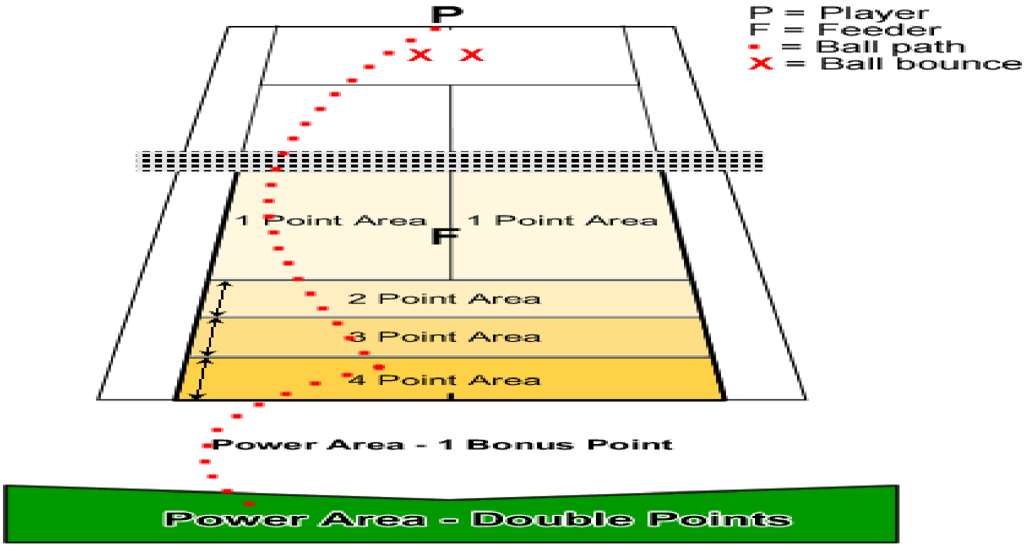
h. Ground Strikes Depth Test

The test will be conducted using the areas marked with the letters 'P' and 'F' in the visual. The ball feeder (F) will feed 10 balls towards the area marked 'x x' in front of the participant (P) at a predetermined speed and height. The participant will respond to these balls with 5 forehand and 5 backhand strokes alternately. During this process, the positions of both the participant and the ball feeder, as well as the areas where the strokes are made, are of great importance for the reliability of the test.

In the event that the athlete's ball goes out of bounds or touches the net and falls, 0 points will be awarded. If the ball lands on the tennis court, points will be awarded as follows:

- Based on the initial contact area, 1, 2, 3, or 4 points will be awarded.
- Based on the second contact area:
    - If the ball lands within the tennis court, 0 points will be awarded.
    - If the ball lands in the "Power Zone +1 Point" area, 1 additional point will be awarded.
    - If the ball lands in the "Power Zone Double Points" area, the points earned will be multiplied by 2.

- An additional point will be awarded for each subsequent contact within the court.
- The maximum score an athlete can achieve in this test is 90 points (10 x 4 x 2 + 10). (12).



2.3. Analysis of Data

A priori power analysis was conducted using GPower 3.1 to determine the required sample size. SPSS 20.0 software was used for statistical analysis of the data collected at the end of the study. Repeated measures ANOVA was employed to compare the means of the obtained data. Correlation analysis was performed to examine the correlation between the groups who performed plyometric training and those who did not. Non-parametric tests were used when data did not exhibit a normal distribution. Data distribution was summarized using minimum, maximum, mean, and standard deviation values. A significance level of 0.05 was adopted for all statistical analyses.

3. Results

The study sought to determine the effects of plyometric training on agility, balance, flexibility, and ground contact time in 9-12 year-old tennis players. In this section, the data analysis is presented.

Tablo 4.1: Comparison of pre- and post-test data in the experimental group

		Ort.	SS	t	p
Flamingo balance test (sn)	Pre test	1,05	0,45	**3.087**	**0.018**
	Post test	0,46	0,34		
Flexibility right	Pre test	26,50	4,14	-1.732	0,127
	Post test	28,00	2,13		
Flexibility left	Pre test	25,62	3,58	**-2,904**	**0,023**
	Post test	28,50	1,41		
Agility test	Pre test	7,00	0,50	**4,652**	**0,002**
	Post test	6,60	0,36		
Ground strokes test	Pre test	29-37	7,00	**-8,526**	**0,001**
	Post test	51,87	5,22		

Table 4.1 presents a comparison of the pre- and post-test data of the experimental group. According to the results of the paired samples t-test, there was a significant difference between the pre- and post-test scores of the experimental group in all parameters except for the right side flexibility ($p<0.05$).

Tablo 4.2: Comparison of pre- and post-test data in the control group

		Ort.	SS	t	p
Flamingo balance test (sn)	Pre test	1,05	0,79	-0,749	0,478
	Post test	0,46	0,92		
Flexibility right	Pre test	26,12	2,35	-0,918	0,389
	Post test	25,25	1,83		
Flexibility left	Pre test	25,50	2,77	-0,956	0,371
	Post test	26,37	2,97		
Agility test	Pre test	7,16	0,62	-0,104	0,920
	Post test	7,17	0,56		
Ground strokes test	Pre test	30,62	15,64	-1,528	0,170
	Post test	32,62	15,37		

Table 4.2 presents a comparison of the pre- and post-test data of the control group. According to the results of the paired samples t-test, there was no significant difference between the pre- and post-test scores of the control group in any of the parameters ($p<0.05$).

Tablo 4.3: Comparison of pre-post test differences between groups

		n	Ort.	SS	t	p
Flamingo balance test (sn)	Experimental Group	8	-0,58	0,53	**-2,59**	**0.021**
	Control Group	8	0,16	0,61		
Flexibility right (cm)	Experimental Group	8	1,50	2,44	1,84	0,086
	Control Group	8	-0,87	2,69		
Flexibility left (cm)	Experimental Group	8	2,87	2,79	1,48	0,087
	Control Group	8	0,87	2,58		
Agility test	Experimental Group	8	-0,40	0,24	-3,63	0,160
	Control Group	8	0,00	0,20		

Ground strokes test	Experimental Group	8	22,50	7,46	**6,95**	**0,001**
	Control Group	8	2,00	3,70		

Table 4.3 presents a comparison of the pre-post test differences between groups. According to the independent samples t-test results, while there was no significant difference between groups in terms of right-left flexibility and agility, there was a significant difference in favor of the experimental group in other parameters ($p<0.05$).

4. Discussion and Conclusion

When comparing the pre- and post-test parameters of the experimental group, a significant difference was observed in all parameters except for right side flexibility. No significant differences were found when comparing the pre- and post-test parameters of the control group. When comparing the difference between the pre- and post-test parameters of the experimental and control groups, significant differences were observed in favor of the experimental group in the flamingo balance test and groundstroke test.

The results of Öner's (2021) study demonstrated a significant enhancement in balance abilities among 11-13-year-old tennis players following a 10-week plyometric training intervention (Öner, 2021).

Akcinar’s 2014 study on 11-12 year old soccer players revealed that an 8-week plyometric training program significantly improved the participants’ balance performance compared to a control group (Akçınar, 2014).

Bouteraa et al. (2006) found that a plyometric training program significantly improved balance performance in basketball players. These results support the notion that plyometric training can be an effective method for enhancing overall physical capacity in athletes (Bouteraa et al., 2006).

Cavdar's 2006 study demonstrated that an 8-week plyometric training program, which included exercises such as box jumps and depth jumps, significantly improved balance performance ($p<0.05$) as measured by the balance board test in young athletes (Çavdar, 2006).

Genç et al. (2019) demonstrated that a 12-week plyometric training program, which included exercises such as box jumps and depth jumps, significantly improved dynamic balance ($p<0.05$) as measured by the Y-balance test in young handball players (Genç et al, 2019).

Turgut’s 2017 study demonstrated that an 8-week plyometric training program, which included exercises such as box jumps and depth jumps, significantly improved balance performance ($p<0.05$) as measured by the balance board test in high school male handball players (Turgut, 2017).

The results of our study are consistent with those of previous studies on the positive effects of plyometric training on balance. This finding reinforces the reliability of plyometric training as a training method for improving balance.

Kılıç's 2021 study demonstrated that a 6-week plyometric training program, which included exercises such as box jumps and depth jumps, significantly improved hamstring flexibility ($p<0.05$) as measured by the sit-and-reach test in 10-14 year old female volleyball players (Kılıç, 2021).

Cavdar's 2006 study, while primarily investigating the impact of plyometric training on jumping performance, also found a significant improvement in flexibility among the participating students (Çavdar, 2006).

In a study conducted by İnce in 2018, the effects of an 8-week plyometric training program on flexibility and other physiological parameters were examined in athletes aged 17-22. The results revealed significant improvements in the experimental group compared to the control group (İnce, 2018).

A 2019 study by Göktaş showed that plyometric training can significantly improve flexibility in 14-17-year-old football players. In this study, players were divided into two groups, one of which received plyometric training. The group that did the plyometric training showed greater improvements in flexibility tests (Göktaş, 2019).

In a study conducted by Delihacıoğlu in 2023, a plyometric training program implemented with 10-12-year-old male volleyball players resulted in a significant increase in their flexibility levels. No such improvement was observed in the control group (Delihacıoğlu, 2023).

The statistical results of our study do not align with those of the studies we reviewed in our literature search. Typically, plyometric exercises designed based on the stretch-shortening cycle aim to enhance the strength and power characteristics of the lower extremity muscles, thereby improving athletes' performance. These exercises significantly improve the rate of force development, anaerobic power, and neuromuscular coordination, making them a popular choice, especially in sports that require jumping and speed (Makaruk H, Sacewicz T, 2010).

Plyometric exercises, characterized by explosive movements and ground impact forces, can pose a significant risk of microtrauma to the lower extremity joints and muscles, particularly in athletes who may not have adequate preparation or conditioning (Hoffman, 2002)

Given these findings, it can be inferred that the plyometric training protocols employed did not positively influence flexibility parameters.

Ertem et al. (2013) investigated the effects of coordination development training on the forehand and backhand skills of 12-14-year-old female tennis players. Statistical analysis of the data obtained from ITN sensitivity and power tests revealed significant differences between the groups (Ertem et al., 2013).

Research on novice tennis players has shown that an 8-week plyometric training program can have a positive impact, particularly on the accuracy of their serves (Salonikidis K, Zafeiridis A, 2008).

Gökbel's (2019) study examined changes in AOS (Agility, Quickness, Speed) scores of tennis players and reached significant findings. The study demonstrated that tennis players can significantly increase their AOS scores through regular training. This proves that agility, quickness, and speed, which directly affect tennis performance, can be developed (Gökbel, 2019).

Keskin et al. (2016) conducted a study to scientifically investigate the effects of tennis training on athletes' performance. The study evaluated the impact of an 8-week training program on athletes' ITN ratings, depth and power of forehand and backhand strokes, and volleying skills, filling a significant gap in tennis training research (Keskin et al., 2016).

Ölçücü (2011) conducted a study and concluded that plyometric training positively affected the speed and accuracy of tennis players' serves, forehands, and backhands. This study provides a significant finding for athletes and coaches who want to improve tennis performance (Ölçücü, 2011).

The study conducted by Fortun in 1997 examined the positive effects of plyometric training on upper extremity strength, specifically the strength of the internal rotator muscles of the shoulder. The study results demonstrated that plyometric training significantly improved performance in throwing and pitching movements by strengthening this muscle group (Fortun, 1997).

The results of our study are consistent with existing literature, which suggests that plyometric training can enhance jump depth. Our findings demonstrate a significant increase in jump depth following the implemented plyometric training program.

Öner's 2021 study found that a 10-week training program, conducted three times a week, positively impacted the agility and speed performance of 11-13-year-old tennis players. This study once again emphasizes the importance of training programs focused on the physical development of young tennis players (Öner, 2021).

Akçınar's 2014 study investigated the effects of plyometric training on balance and soccer-specific skills in 11-12-year-old athletes and yielded interesting results. The positive changes observed in the Illinois agility test scores, in particular, indicate that plyometric training significantly improves agility (Akçınar, 2014).

Güzel's 2020 study investigated the effects of plyometric training on agility performance in female volleyball players. The results showed a statistically significant improvement in agility test performance after an 8-week plyometric training program, further confirming the positive effects of plyometric training on agility development (Güzel, 2020).

The study conducted by Yarayan and Müniroğlu in 2020 on the effects of plyometric training on the agility performance of 13-14-year-old young footballers is quite significant in revealing the positive effects of plyometric training on agility performance. This study shows that plyometric training is an effective method for developing agility not only in football but also in other sports (Yarayan and Müniroğlu, 2020).

In their 2020 study, Ahmad and Jain highlighted that an 8-week plyometric training program significantly improved agility performance in 100 young female volleyball players (Ahmad and Jain, 2020).

Alp and Mansuroğlu (2021) conducted a study to explore the effects of a 6-week plyometric training intervention on the agility of volleyball players. Participants completed 30 minutes of plyometric exercises three times per week in addition to their regular training regimen. The findings revealed a significant positive correlation between plyometric training and agility performance (Alp and Mansuroğlu, 2021).

A study by Özbar and colleagues in 2020 revealed that an 8-week plyometric training intervention led to significant improvements in agility among a group of 13-15-year-old male soccer players (Özbar, 2020).

A study by Vaczi and colleagues revealed a significant difference in pre- and post-test results following a 6-week short-duration, high-intensity plyometric training program in 24 football players, indicating a positive impact on strength and agility (Vaczi, 2013).

In their 2023 study titled "Plyometric Training Programs in Handball: A Systematic Scoping Review," Rocha Henrigue et al. investigated the effects of plyometric training on selected physical parameters in handball players. They found that plyometric training, performed twice a week, had a positive impact on agility parameters in handball players (Henrigue et al, 2023).

Pamuk et al. (2022) conducted a study investigating the physiological adaptations to plyometric and resistance-plyometric training in basketball players. The study findings showed that these training programs significantly increased lower extremity muscle strength, but also led to a statistically significant decrease in agility and sprint performance (Pamuk et al., 2022).

Delihacıoğlu (2023) investigated the effects of plyometric training on motor development in 10-12-year-old male volleyball players. The study found that there was no statistically significant improvement in agility test performance following the plyometric training program applied to the experimental group. This result contradicts the general belief that plyometric training always increases agility in all age groups and sports, suggesting that the expected effect was not observed in this specific study group (Delihacıoğlu, 2023).

The statistical results of our study align with those of previous studies. The plyometric training program had a positive impact on agility parameters in both the experimental and control groups, as indicated by the pre-post test difference scores, except for the between-group comparison table. The observed improvement in agility performance following the 4-week plyometric training program can be attributed to adaptations in the lower extremity muscles. Specifically, the increase in explosive force, coupled with enhanced eccentric and concentric contraction velocities, contributed to faster and more efficient agility movements.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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