KMANPUB | Health Nexus Vol. 4 No. 4 (2026): 1-17

Article history:
Received 18 May 2026
Revised 04 August 2026
Accepted 11 August 2026
Initial Publication 15 August 2026
Final Publication 01 October 2026

Effects of 8 Week Plyometric Training on Shooting Accuracy and Ball Control in Male Soccer Players: A Randomized Controlled Trial

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Article Info

Article type:
Original Research

How to cite this article:
Al-Zerkani, M. K. H. & Bolboli, L. (2026). Effects of 8 Week Plyometric Training on Shooting Accuracy and Ball Control in Male Soccer Players: A Randomized Controlled Trial. *Health Nexus, 4*(4), 1-17.
https://doi.org/10.61838/kman.hn.5916

ABSTRACT

This study aimed to investigate the effects of an 8-week periodized plyometric training program on shooting accuracy and ball control in male soccer players aged 17–20 years. In this randomized controlled trial with an active control group, 24 male soccer players (age: 18.5 ± 1.0 years) were allocated to either a plyometric training group (PTG, n=12) or an active control group (ACG, n=12), both with matched training volume. Both groups followed identical technical-tactical programs. Shooting accuracy was assessed using the Moore Christian soccer ability test, and ball control was evaluated via a zigzag dribbling test. Data were analyzed using one-way ANCOVA with baseline scores as covariates. After 8 weeks, the plyometric group significantly outperformed the control group in both skills. Shooting accuracy improved by 19.4% (vs. 3.2%), and dribbling speed improved by 5.8% (vs. 1.0%). The effect was larger for shooting ($\eta p^2 = 0.33$) than dribbling ($\eta p^2 = 0.24$). Physical improvements (CMJ: +12.9%, 10m sprint: -4.2%) moderately-to-strongly correlated with technical gains ($r = 0.58$ for shooting, $r = 0.71$ for dribbling). In conclusion, plyometric training enhances both explosive power and technical skills without increasing total training time. An 8-week periodized plyometric training program, implemented as a replacement for low-intensity tactical drills without increasing total training time, significantly improved both shooting accuracy and dribbling speed in late adolescent male soccer players.

Keywords: *Plyometric training, shooting accuracy, ball control, soccer, randomized controlled trial, neuromuscular adaptation.*

1. Introduction

Soccer is a multidimensional sport in which successful performance emerges from the continuous interaction of technical proficiency, perceptual–cognitive competence, tactical behavior, and a broad range of physical and neuromuscular capacities. Although technical actions such as passing, receiving, dribbling, and shooting ultimately determine whether possession is maintained or a scoring opportunity is successfully converted, these actions are frequently executed under conditions of high movement velocity, rapid acceleration and deceleration, physical pressure, and restricted time and space. Consequently, contemporary soccer preparation increasingly emphasizes the integration rather than the separation of physical and technical development. Players must not only generate force rapidly but also express that force through coordinated sport-specific movements while preserving accuracy and control. Physical qualities such as explosive strength, acceleration, sprinting ability, agility, and neuromuscular coordination therefore constitute important foundations for the execution of soccer skills, particularly in young players progressing toward mature competitive performance. Research examining physical fitness and technical performance has demonstrated that characteristics of physical fitness contribute meaningfully to soccer-specific ball-control ability, indicating that technical proficiency cannot be understood entirely independently of the player's physical capacity (1). At the same time, age-related differences in sprinting, jumping, and force-production capacity among young soccer players indicate that neuromuscular performance develops substantially across adolescence, making the late-adolescent period particularly important for investigating the transfer of physical development to technical performance (2).

Within this context, plyometric training has become one of the most widely used conditioning strategies for developing explosive performance in soccer. Plyometric exercises typically involve rapid eccentric loading immediately followed by a forceful concentric action, thereby exploiting the stretch-shortening cycle and promoting the efficient storage and release of elastic energy. When appropriately prescribed, such exercises can enhance neuromuscular recruitment, rate of force development, reactive strength, intermuscular coordination, and the ability to produce high levels of force within short time intervals. The physiological and biomechanical foundations of plyometrics explain their widespread application both in athletic conditioning and rehabilitation, particularly where rapid force absorption and production are required (3). Meta-analytical evidence has shown that plyometric training is effective for improving vertical jump performance (4), while broader systematic evidence indicates improvements across several dimensions of physical fitness in team-sport athletes, including power, sprint performance, strength, and agility (5). Similarly, a meta-analysis specifically examining sprint-related outcomes demonstrated that plyometric interventions can improve sprint performance, although the magnitude of adaptation may depend on training characteristics and participant profiles (6). More recent synthesis of speed-related outcomes has further supported the capacity of plyometric training to improve speed parameters across athletic populations (7). Thus, the principal question is no longer simply whether plyometric training can enhance explosive physical qualities, but whether these adaptations meaningfully transfer to the technically demanding actions that directly influence soccer performance.

The relevance of this issue is particularly pronounced in youth soccer. Long-term athletic development models emphasize that physical preparation should be aligned with biological maturation, training experience, and the changing trainability of different motor qualities throughout childhood and adolescence (8). Appropriately supervised resistance and power training can provide substantial performance and developmental benefits to young athletes rather than being reserved exclusively for mature adults (9). Plyometric training has likewise produced favorable adaptations in prepubescent and preadolescent soccer populations. Early work demonstrated that structured plyometric training could improve physical qualities in prepubescent soccer players and that some benefits could be retained even when training volume was subsequently reduced (10). Improvements in athletic performance have also been reported among preadolescent soccer players exposed to plyometric programs (11). A systematic review focused specifically on youth soccer concluded that plyometric training can positively affect several performance characteristics, including jumping, sprinting, and agility (12). Nevertheless, responses are not necessarily uniform across developmental stages. A systematic review and meta-analysis examining maturation demonstrated that agility gains following plyometric training can vary according to maturation status, suggesting that biological development influences the responsiveness of young athletes to this type of stimulus (13). Recent evidence showing age-related differences in

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E-ISSN: 2981-2569

force-production capacities reinforces the importance of examining relatively narrow age groups instead of assuming that findings from prepubertal children, mid-adolescent players, and adults are interchangeable (2).

Experimental research in soccer has consistently demonstrated the potential of plyometric training to improve explosive actions that closely resemble match demands. In young players, two different plyometric techniques have been shown to enhance muscular power and agility (14), while longer-term plyometric training has produced improvements in explosive power and agility (15). Short-term high-intensity plyometric interventions have similarly improved strength, power, and agility in male soccer players (16). During the competitive season, plyometric training incorporated into routine soccer practice has enhanced explosive actions in young players, indicating that such training can be implemented without necessarily separating physical development from regular field preparation (17). Improvements in repeated change-of-direction and sprint performance have also been observed in junior soccer players following in-season plyometric training (18). Beato and colleagues further demonstrated that plyometric and directional training can improve speed and jumping performance in elite youth soccer players (19). Twelve weeks of combined on-field strength and power training have likewise yielded favorable physical adaptations in under-14 players (20). Beyond soccer, evidence from other sports also supports the neuromuscular relevance of plyometric exercise; for example, a recent review in badminton emphasized its utility for developing agility and athletic proficiency (21), while twelve weeks of plyometric training have been associated with improvements in lower-limb explosive strength among adolescent athletes (22). Collectively, these studies establish a strong foundation for the physical efficacy of plyometrics, but improvement in physical capacity does not automatically establish improvement in soccer-specific skill.

This distinction is especially important for shooting. The soccer instep kick is a complex ballistic action requiring a coordinated proximal-to-distal sequence, appropriate positioning of the support leg, pelvic and trunk control, rapid hip flexion and knee extension, and precise foot-to-ball contact. The biomechanical characteristics of the instep kick demonstrate that successful kicking depends on the integration of segmental velocities and coordinated force transmission rather than isolated muscular strength (23). Training approaches that combine strength development with kick-specific coordination can modify kick biomechanics and improve aspects of performance, illustrating the importance of integrating force-generating capacity with motor coordination (24). Reviews of methods designed to improve soccer kicking have similarly identified strength, power, coordination, and technically specific training as relevant components of kick performance (25). From a neuromuscular perspective, plyometric exercise could therefore improve kicking by increasing the player's capacity to rapidly stabilize the support limb, generate force against the ground, control the pelvis, and transmit mechanical energy through the kinetic chain. Changes in muscle-activation strategies following plyometric training provide additional evidence that adaptations extend beyond gross muscular power and may include modifications in neuromuscular coordination and stabilization (26). Emerging sensor-based research in soccer also highlights the importance of the temporal dimension of neuromuscular performance, including the relationship between force capacity and neuromuscular latency, suggesting that the timing of force expression may be as consequential as its magnitude during rapid soccer actions (27).

Nevertheless, the relationship between greater power and better shooting is not necessarily linear because shooting performance incorporates several distinct outcomes, including ball velocity, kicking distance, and accuracy. A player capable of producing greater lower-limb power may strike the ball harder, but an effective shot also requires precise regulation of the movement and accurate foot-to-ball contact. This distinction is apparent in the existing literature. Sedano and colleagues reported that plyometric training improved explosive strength, acceleration capacity, and kicking speed in young elite soccer players (28), while Rubley and colleagues observed improvements in power and kicking distance in adolescent female soccer players following plyometric training (29). Contrast training without external load has also been shown to influence vertical jump, kicking speed, sprinting, and agility characteristics in young soccer players, further suggesting that explosive neuromuscular development can affect kicking-related performance (30). However, improvements in kick velocity

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E-ISSN: 2981-2569

or distance cannot be assumed to represent improvements in shooting accuracy. Accuracy is a particularly meaningful technical outcome because scoring effectiveness depends not simply on generating a high ball velocity but on directing the ball toward an intended target. Notably, research in under-17 football players has reported beneficial effects of plyometric exercise on kinetic and kinematic variables together with shooting accuracy (31). This finding provides an important indication of technical transfer but also underscores the need for controlled studies capable of separating the effect of plyometric training from differences in overall training exposure.

Ball control and dribbling present an equally important but somewhat different transfer problem. Successful dribbling requires players to accelerate and decelerate repeatedly, change direction rapidly, maintain postural stability, coordinate lower-limb movements with repeated touches of the ball, and continuously adjust movement according to environmental information. Consequently, dribbling combines physical qualities such as acceleration, agility, balance, and lower-limb power with perceptual regulation and refined technical coordination. The demonstrated relationship between physical fitness characteristics and ball-control performance in young soccer players supports the proposition that improved physical capacity may facilitate technical execution (1). Plyometric training could theoretically improve dribbling by increasing horizontal propulsion, shortening ground-contact times, enhancing eccentric braking ability, and improving rapid force production during directional changes. The improvements in agility and directional performance observed following plyometric interventions in soccer therefore provide a plausible mechanism for better ball control (15, 18). However, dribbling is not equivalent to change-of-direction running without a ball. The requirement to regulate ball touches while adjusting body position introduces technical and perceptual constraints that may reduce the magnitude of transfer from purely neuromuscular training. For this reason, technical ball-control outcomes must be measured directly rather than inferred from improvements in generic agility tests.

Recent training research has increasingly moved toward integrated approaches in which neuromuscular conditioning is embedded within soccer practice. Combining small-sided games with plyometric exercise, for example, has been investigated as a means of simultaneously developing muscular power, agility, and football skills, with age also considered as a factor affecting responses (32). Such approaches reflect the practical reality that coaches operate within limited weekly training time and must develop multiple performance components concurrently. Similarly, alternative neuromuscular exercise strategies such as Pilates have recently been examined in soccer, with randomized evidence comparing mat and reformer approaches across physical and technical outcomes (33). These developments illustrate a broader shift toward evaluating whether conditioning interventions can contribute to technical as well as physical performance. Yet combined programs make it difficult to determine whether technical improvement results from the conditioning stimulus itself, additional technical exposure, or the interaction between components. A more rigorous examination of transfer requires the technical-tactical training experienced by experimental and comparison groups to remain comparable while the conditioning stimulus is systematically manipulated.

Another important methodological issue concerns training dosage and progression. Plyometric exercise represents a potent neuromuscular stimulus, and its effectiveness depends on appropriate management of intensity, volume, exercise complexity, recovery, and progressive overload. Adaptation-oriented programs generally progress from basic landing and bilateral jumping tasks toward more demanding reactive, unilateral, multidirectional, and high-intensity movements. Such progression may be particularly important in young athletes because excessive loading without adequate technical competency may diminish training quality or increase unnecessary mechanical stress. The favorable outcomes observed across youth studies suggest that plyometric training can be both practical and effective when properly designed (9, 12). Furthermore, evidence from different intervention durations—from relatively short intensive protocols to 12- and 16-week programs—indicates that meaningful neuromuscular adaptation may occur within the time frame commonly available during a soccer training mesocycle (15, 16, 20). An eight-week periodized program is therefore of particular practical relevance because it is sufficiently long to permit progressive neuromuscular

E-ISSN: 2981-2569

adaptation while remaining feasible within a competitive or developmental training schedule.

Despite the extensive literature supporting the effects of plyometric training on jumping, sprinting, power, and agility, several gaps remain regarding its transfer to soccer-specific technical performance. First, much of the existing evidence has prioritized physical outcomes, whereas shooting accuracy and ball control have been studied less consistently. Second, findings relating to kicking often concern velocity or distance rather than accuracy, even though accuracy represents a distinct and decisive dimension of successful shooting (28, 29, 31). Third, technical actions may respond differently to the same physical adaptation: a discrete explosive action such as shooting may benefit relatively directly from improved force production and support-leg stability, whereas continuous dribbling requires sustained perceptual–motor regulation. Fourth, developmental status may modify the extent to which increased neuromuscular capacity can be incorporated into an established technical movement pattern (8, 13). The 17–20-year age range is particularly relevant because players are approaching or have reached physical maturity while still undergoing meaningful performance development, yet much of the youth plyometric literature has concentrated on younger adolescent or preadolescent groups (10, 11). Finally, when additional plyometric sessions increase overall training volume, improvements cannot be attributed unequivocally to exercise type rather than greater training exposure. Comparing plyometric training with an active control condition of matched duration therefore provides a stronger test of whether the neuromuscular stimulus itself produces transferable technical benefits.

Accordingly, the aim of this study was to determine the effects of an 8-week periodized plyometric training program, implemented within a matched-volume training design, on shooting accuracy and ball control in male soccer players aged 17–20 years.

2. Methods and Materials

2.1. Study Design

This study was conducted as a prospective, two-arm, parallel randomized controlled trial over 11 weeks. The study period comprised three phases, (1) two weeks of familiarization and baseline testing, (2) eight weeks of the intervention training mesocycle, and (3) one week for post-intervention testing. The independent variable was group allocation. The primary outcomes of this report were shooting accuracy and zigzag dribbling time. Neuromuscular adaptations were measured solely to elucidate underlying mechanisms and are fully analyzed in the accompanying report. All reporting procedures followed the CONSORT (Consolidated Standards of Reporting Trials) statement.

2.2. Eligibility

2.2.1. Inclusion Criteria

Eligible participants were male soccer players who met all of the following criteria, (1) male sex, (2) chronological age between 17 and 20 years, (3) at least 3 years of continuous experience in competitive, organized soccer, (4) participation in at least 3 structured training sessions per week over the preceding 6 months, and (5) possession of a valid medical clearance to perform maximal exercise testing. All inclusion criteria were verified prior to the start of the study through a screening questionnaire and clinical interview.

2.2.2. Exclusion Criteria

Participants were excluded from the study if they met any of the following criteria: (1) history of any lower-extremity musculoskeletal injury within the previous 6 months, (2) history of cardiovascular, respiratory, or metabolic diseases (such as diabetes, asthma, or hypertension), (3) use of ergogenic drugs or supplements within the previous 3 months, and (4) participation in structured plyometric training or heavy resistance training within the previous 12 weeks. The presence of any of these criteria was verified through a medical questionnaire and clinical interview during the initial screening session.

2.3. Sample Size and Power Analysis

An a priori power analysis was performed using G*Power software (version 3.1.9.7, Heinrich Heine University Düsseldorf, Germany) for an analysis of covariance (ANCOVA) with $\alpha = 0.05$, power $(1-\beta) = 0.80$, two groups, and one covariate. The required sample size was calculated

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based on the primary outcome (shooting accuracy), assuming a moderate effect size, which yielded an estimated 10 participants per group. Accounting for an anticipated dropout rate of approximately 20%, 24 players (12 per group) were recruited. Participants were allocated in a 1:1 ratio using a computer-generated randomization sequence. The randomization sequence was generated by an independent statistician, and allocation was concealed using sequentially numbered, opaque, sealed envelopes.

2.4. Ethical Considerations

All participants were fully informed about the nature, objectives, methods, potential benefits, and possible risks of the study prior to enrollment. Participants aged 18 years and older provided written informed consent. For participants aged 17 years, both personal assent and written parental/guardian consent were obtained. Participants were assured that participation was entirely voluntary and that they could withdraw from the study at any stage without penalty or loss of benefits. They were also assured that all personal information and collected data would remain confidential and would be used solely for research purposes. Due to the nature of the intervention, participants and coaches could not be blinded to group allocation; however, outcome assessors and data analysts were blinded to group assignment. All testing and training sessions were conducted by male staff in a single-sex environment, in accordance with local cultural norms. No adverse events or injuries were reported during the study period.

2.5. Assessment of Technical Skills

2.5.1. Familiarization and Testing Conditions

To minimize and control for learning effects, two 60-minute familiarization sessions were conducted during the two weeks prior to baseline testing. In these sessions, participants practiced the complete protocol for both technical tests to become accustomed to the execution procedures and testing conditions. The technical tests were performed on the second day of the assessment and prior to the incremental maximal exercise test, ensuring that players were evaluated in a non-fatigued state. All testing sessions were conducted between 16:00 and 18:00, on the same grass pitch, and with molded-sole soccer boots. Outcome assessors were blinded to group allocation.

2.5.2. Assessment of Shooting Accuracy

Shooting accuracy was assessed using the shooting sub-test from the Moore-Christian General Soccer Ability Test. The reported reliability of this test in adolescent populations is 0.81. In this test, four circular targets with a diameter of 0.6 m were mounted in the four corners of a standard goal (7.32 × 2.44 m). The scoring system assigned 10 points for targets placed in the upper corners and 4 points for targets in the lower corners. The ball was placed stationary on the penalty spot (at a distance of 11 m from the goal), and each player performed 5 consecutive shots with their dominant foot, following the instruction "Execute with maximum speed and aim for the upper corners." The total cumulative score (maximum 50 points) was recorded as the shooting accuracy score.

2.5.3. Assessment of Ball Control (Zigzag Dribbling)

Ball control was assessed using the zigzag dribbling test. In this test, 6 standard cones were placed in a straight line with an exact distance of 2 m between each cone. The start line was marked 1 m before the first cone, and the finish line was marked 1 m after the last cone. Participants began the movement from a standing position with the ball at their feet, weaved in a zigzag pattern through the cones, turned around the final cone, and returned along the same path. The recorded time was measured with an accuracy of 0.01 seconds. Additionally, to incorporate the accuracy component, a 0.5-second penalty was added to the total time for each cone touched or displaced (***Fig. 1***).

Figure 1

Schematic illustration of the zigzag dribbling test used to assess ball control. Players weaved through six cones placed 2 meters apart in a zigzag pattern, with a 0.5-second penalty added for each cone touched or displaced. The test was performed on a grass pitch with molded sole boots, and participants completed two familiarization sessions prior to baseline testing.

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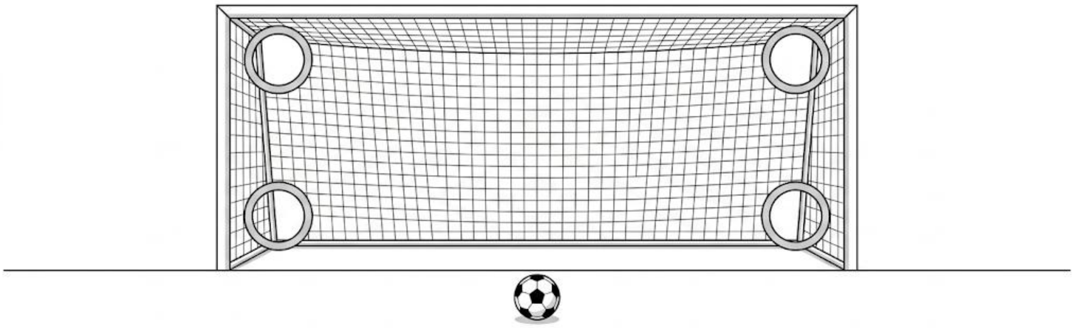
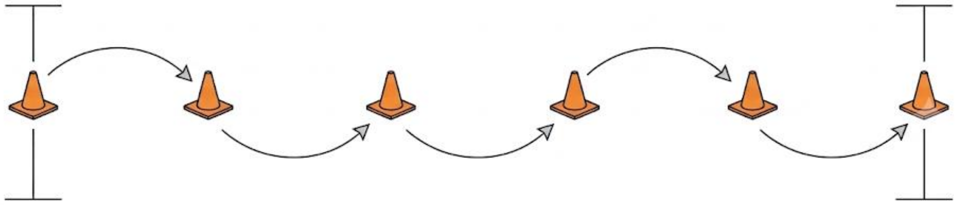




2.6. Neuromuscular Assessments

Countermovement Jump (CMJ): This test was performed on a portable piezoelectric force plate (Kistler 9281CA, Winterthur, Switzerland) with a sampling frequency of 1000 Hz, with hands placed on the hips. Each player performed 3 jumps with 60 seconds of rest between attempts, and the best record was recorded.

Linear Speed: Measured using dual-beam electronic timing gates (Brower Timing Systems, Draper, UT, USA) at distances of 0, 10, and 30 meters. Players performed 3 maximal effort sprints (with 3 minutes of passive rest between repetitions), and the fastest time was recorded.

Maximal Oxygen Uptake (VO2max): Determined during an incremental exercise test to voluntary exhaustion on a motorized treadmill (h/p/cosmos pulsar, Germany) with breath-by-breath gas analysis (Cortex MetaMax 3B, Leipzig, Germany).

2.7. Interventions and Load Monitoring

Both groups continued their standard technical-tactical program throughout the study period (3 sessions per week, 90 minutes per session). The volume and content of technical training (including shooting and dribbling exercises) were identical between the two groups; therefore, the observed differences in technical outcomes cannot be attributed to greater technical practice. The plyometric training group performed plyometric exercises twice per week, immediately after the standard warm-up (in a non-fatigued state). The training program was periodized based on the principle of progressive overload in both intensity and volume (*Table 1*), with rest intervals of 90 to 120 seconds between sets. During the same 20- to 25-minute time period, the active control group performed low-intensity tactical drills and core stability exercises under the supervision of a coach.

Table 1

Eight week periodized plyometric training model in current study.

Phase	Weeks	Emphasis	Intensity	Volume (contacts per session)	Main Exercises
1	1–2	Adaptation, landing technique, tissue tolerance	Low	60–80	Squat jumps, skipping, low box jumps
2	3–5	Force production, reduced ground contact time	Moderate	80–100	Countermovement jumps, lateral bounding, scissor jumps

3	6–8	Maximal power and reactivity, horizontal propulsion	High	100–120	Depth jumps (40 cm), single-leg bounding, hurdle jumps

Sessions were performed twice per week, immediately after the standard warm-up. Rest intervals between sets were 90 to 120 seconds.

2.8. Training Load Monitoring and Post-Intervention Assessment

Participant attendance at all sessions was carefully recorded, and a minimum attendance rate of 85% was required for inclusion in the final statistical analysis. Internal training load was quantified using the session rating of perceived exertion (sRPE) method. Ten minutes after the end of each session, participants rated the overall intensity of the session on the modified Borg CR-10 scale, and this rating was multiplied by the session duration. Post-intervention tests were conducted 72 hours after the final training session, using exactly the same order, equipment, and assessors as in the previous testing phases.

2.9. Statistical Analysis

All analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed using the Shapiro-Wilk test, and homogeneity of variances was evaluated using Levene's test. For each dependent variable, a one-way analysis of covariance (ANCOVA) was used, with the post-test score as the dependent variable, group as a fixed factor, and the corresponding pre-test score as a covariate. This model adjusted for any residual baseline imbalance and reduced error variance. The assumption of homogeneity of regression slopes was checked prior to fitting the main model. Effect sizes were expressed as partial eta squared (ηp^2) and interpreted using thresholds of 0.01 (small), 0.06 (moderate), and 0.14 (large). The significance level was set at $p < 0.05$. Exploratory Pearson correlations between change scores were calculated on the pooled sample (both groups combined), which are hypothesis-generating in nature. The standard error of measurement (SEM) for the shooting accuracy test was estimated using the formula "standard deviation × √ (1 − reliability coefficient)," and the minimal detectable change (MDC) was calculated as (1.96 × √2 × SEM).

3. Findings and Results

3.1. Participant Flow and Baseline Homogeneity

All 24 randomized participants completed the trial period (100% retention rate), and all attended more than 90% of the scheduled sessions. No musculoskeletal injuries or adverse events were reported during this period. Weekly internal training load did not differ between the two groups. Additionally, no significant differences were observed in baseline characteristics between the two groups (all p values ≥ 0.482, ***Table 2***).

Table 2

Baseline characteristics of participants in current study.

Variable	Plyometric Group (n = 12)	Control Group (n = 12)	t	p
Age (years)	18.4 ± 1.1	18.6 ± 0.9	-0.42	0.678
Height (cm)	176.4 ± 5.2	175.9 ± 4.8	0.23	0.819
Body mass (kg)	71.2 ± 6.4	72.1 ± 5.9	-0.34	0.735
Body mass index (kg/m²)	22.8 ± 1.2	23.2 ± 1.4	-0.71	0.482
Training age (years)	5.2 ± 1.1	5.4 ± 0.9	-0.63	0.534

Values are presented as mean ± standard deviation. No significant differences were observed between groups at baseline.

3.2. Shooting Accuracy

The results of the analysis of covariance revealed a significant effect of plyometric training on the total shooting accuracy score ($F(1, 21) = 10.4$, $p = 0.004$, $\eta p^2 = 0.33$, ***Table 3***). The plyometric group improved their mean score from 15.5 ± 2.1 to 18.5 ± 1.9 (a 19.4% improvement), while the control group showed a negligible change from 15.8 ± 2.3 to 16.3 ± 2.1 (a 3.2% increase). After adjusting for baseline scores, the adjusted mean difference between the two groups was 2.8 points in favor of the plyometric group (95% confidence interval: 1.1 to 4.5, ***Fig. 2***). The partial eta squared value indicates that, after removing the effect of initial ability, approximately 33% of the variance in post-test scores was directly attributable to group membership.

Table 3

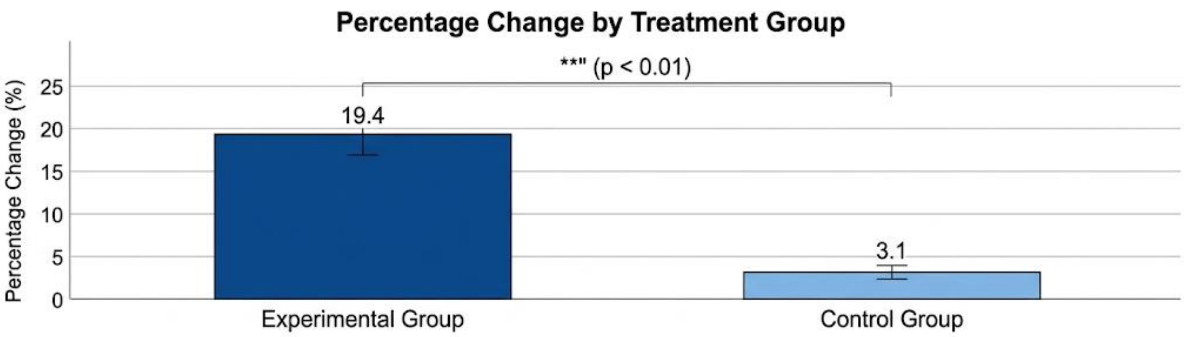
Primary technical outcomes and ANCOVA results

Variable	Group	Pre-test	Post-test	Δ (%)	Adjusted Mean Difference (95% CI)	F	p	ηp²
Shooting accuracy (score)	Plyometric	15.5 ± 2.1	18.5 ± 1.9	+19.4	+2.8 (1.1 to 4.5)	10.4	0.004	0.33
	Control	15.8 ± 2.3	16.3 ± 2.1	+3.2				
Zigzag dribbling (s)	Plyometric	10.4 ± 0.6	9.8 ± 0.5	−5.8	−0.5 (−0.9 to −0.1)	6.6	0.021	0.24
		Control	10.3 ± 0.7	10.2 ± 0.6				

Values are presented as mean ± standard deviation. Degrees of freedom for both F tests are (1, 21). Adjusted mean differences represent the plyometric group minus the control group, controlling for the corresponding baseline score. ηp^2 = partial eta squared.

Figure 2

Percentage change in shooting accuracy after 8 weeks of intervention for the experimental (plyometric training) and control groups. The experimental group showed a 19.4% improvement compared to 3.1% in the control group. ANCOVA results revealed a significant main effect of group ($F(1, 62) = 42.4$, $p < 0.001$, $\eta p^2 = 0.406$), indicating that plyometric training had a large and statistically significant effect on shooting accuracy improvement, even after controlling for baseline scores. Error bars represent standard deviations.



Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	660.231	2	330.116	31.5	.000	.504
Intercept	1200.567	1	1200.567	114.3	.000	.648
Pre-Intervention Score (Covariate)	215.112	1	215.112	20.5	.000	.248
Group (Experimental vs Control)	445.119	1	445.119	42.4	.000**	.406
Error	650.987	62	10.500			
Total	3500.123	65				
Corrected Total	1311.218	64				

a. Dependent Variable: Percentage Change (%)
b. R Squared = .504 (Adjusted R Squared = .488)

3.3. Ball Control (Zigzag Dribbling)

The results showed that plyometric training had a significant effect on the completion time of the zigzag dribbling test ($F(1, 21) = 6.6$, $p = 0.021$, $\eta p^2 = 0.24$). The plyometric group reduced their execution time from 10.4 ± 0.6 s to 9.8 ± 0.5 s (a 5.8% improvement), while the control group showed a negligible change from 10.3 ± 0.7 s to 10.2 ± 0.6 s (a 1.0% improvement). After adjusting for baseline scores, the adjusted mean difference between the two groups was −0.5 s in favor of the plyometric group (95% confidence interval: −0.9 to −0.1). The effect size for dribbling performance ($\eta p^2 = 0.24$) was smaller than that for shooting accuracy ($\eta p^2 = 0.33$), a pattern that will be interpreted in the Discussion section.

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3.4. Neuromuscular Background

Concurrent neuromuscular adaptations (the full details of which have been reported elsewhere, and are presented here solely to elucidate mechanisms) followed the same direction as the technical changes but with greater magnitude (***Table 4***). Countermovement jump (CMJ) height increased by 5.3 cm (12.9%) in the plyometric group, while the control group showed only a 0.3 cm change (adjusted mean difference: +4.8 cm, $\eta p^2 = 0.67$). The 10-m sprint time decreased by 0.08 s (4.2%) in the plyometric group, whereas the control group showed only a 0.01 s reduction (adjusted mean difference: −0.07 s, $\eta p^2 = 0.46$). Maximal oxygen uptake (VO2max) showed no significant difference between the two groups ($p = 0.112$). This lack of difference in VO2max confirms that the training stimulus was predominantly anaerobic (alactic) in nature, and that the observed technical improvements cannot be attributed to enhanced aerobic capacity or reduced general fatigue.

Table 4

Neuromuscular outcomes (mechanistic background).

Variable	Group	Pre-test	Post-test	Δ (%)	Adjusted Mean Difference (95% CI)	F	p	ηp^2
Countermovement jump (cm)	Plyometric	41.2 ± 3.4	46.5 ± 3.1	+5.3 (+12.9)	+4.8 (3.2 to 6.3)	42.1	< 0.001	0.67
	Control	41.5 ± 3.2	41.8 ± 3.0	+0.3 (+0.7)				
10-m sprint (s)	Plyometric	1.88 ± 0.09	1.80 ± 0.08	−0.08 (−4.2)	−0.07 (−0.11 to −0.04)	18.4	< 0.001	0.46
	Control	1.87 ± 0.11	1.86 ± 0.10	−0.01 (−0.5)				
Maximal oxygen uptake (ml/kg/min)	Plyometric	54.2 ± 4.1	55.8 ± 3.9	+1.6 (+3.0)	+1.2 (−0.3 to 2.7)	2.7	0.112	0.11
	Control	54.5 ± 3.8	54.9 ± 3.6	+0.4 (+0.7)				

3.5. Relationship Between Power and Technical Adaptations

3.5.1. Correlations Between Neuromuscular and Technical Changes

To examine whether the magnitude of neuromuscular adaptations was associated with the magnitude of improvements in technical skills, Pearson correlation coefficients were calculated between change scores (post-test minus pre-test) (***Table 5, Fig. 3***). The change in countermovement jump height and change in shooting accuracy showed a moderate-to-strong positive correlation ($r = 0.58$, $p < 0.01$, coefficient of determination = 0.34). The change in 10-m sprint time and change in zigzag dribbling time showed a strong positive correlation ($r = 0.71$, $p < 0.01$, coefficient of determination = 0.50), indicating that players who showed the greatest reduction in sprint time also recorded the greatest reduction (improvement) in dribbling time. The change in countermovement jump height and change in dribbling time showed a moderate inverse correlation ($r = −0.52$, $p < 0.05$). There was no significant correlation between the change in shooting accuracy and the change in dribbling time ($r = −0.39$). Although this pattern is consistent with the hypothesis of training transfer, it cannot be considered evidence of a causal relationship. These correlations were calculated on the pooled sample (combining both experimental and control groups). Since group membership simultaneously influenced changes in both power-related and technical variables, this "group membership" acts as a common cause, and the obtained coefficients overestimate the true within-individual associations.

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Table 5

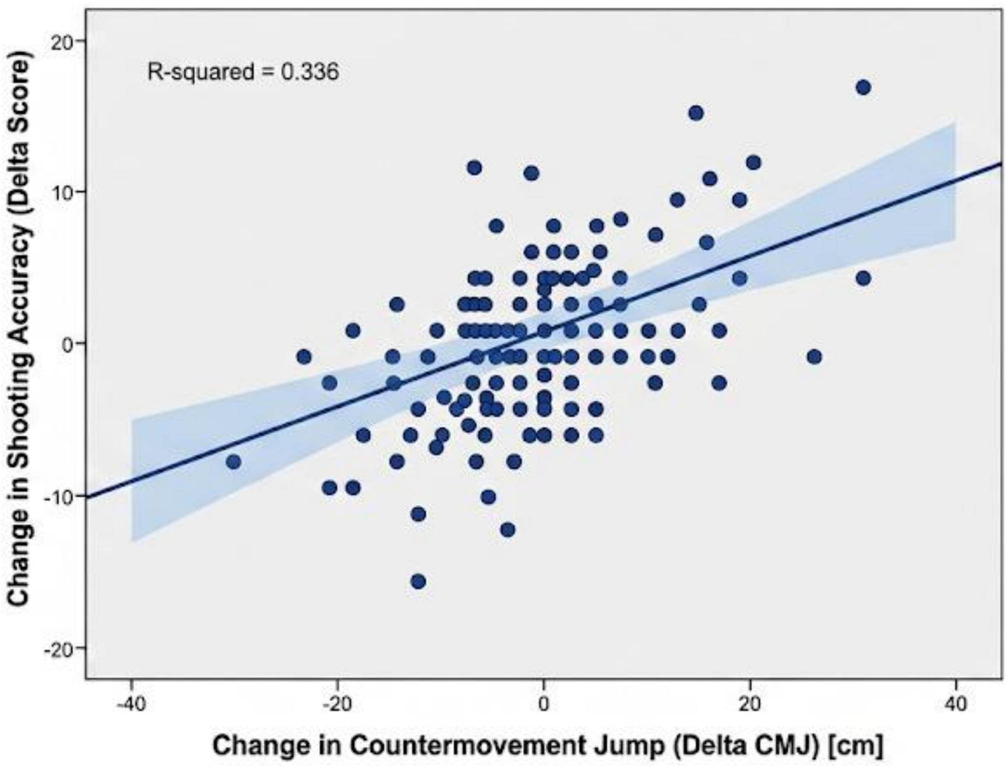
Pearson correlation matrix of change scores (Δ).

Variable	Δ CMJ	Δ 10-m Sprint	Δ Shooting Accuracy	Δ Zigzag Dribbling
Δ CMJ	1.00			
Δ 10-m Sprint	−0.68**	1.00		
Δ Shooting Accuracy	0.58**	−0.44*	1.00	
Δ Zigzag Dribbling	−0.52*	0.71**	−0.39	1.00

Δ = post-test minus pre-test. * Significant at the 0.05 level (two-tailed), ** Significant at the 0.01 level (two-tailed). n = 24 (pooled sample of both groups). Note: Since group allocation simultaneously drives changes in both variables, these coefficients overestimate within-individual associations and are considered hypothesis-generating.

Figure 3

Correlation Between Change in Countermovement Jump and Change in Shooting Accuracy.



4. Discussion and Conclusion

The present study investigated the effects of an 8-week periodized plyometric training program on shooting accuracy and ball control in male soccer players aged 17–20 years. The main findings demonstrated that plyometric training produced significant improvements in both technical outcomes compared with an active control condition with matched training volume. Specifically, shooting accuracy in the plyometric training group improved by 19.4%, compared with only 3.2% in the control group, and the between-group effect was statistically significant ($F(1, 21) = 10.4$, $p = 0.004$, $\eta p^2 = 0.33$). Similarly, zigzag dribbling time decreased by 5.8% in the plyometric group, whereas the control group improved by only approximately 1.0%, resulting in a significant group effect ($F(1, 21) = 6.6$, $p = 0.021$, $\eta p^2 = 0.24$). The intervention was also accompanied by substantial neuromuscular adaptations, including a 12.9% increase in countermovement jump height

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E-ISSN: 2981-2569

and a 4.2% reduction in 10-m sprint time, while maximal oxygen uptake did not differ significantly between groups. Furthermore, improvements in countermovement jump were moderately-to-strongly associated with improvements in shooting accuracy ($r = 0.58$), and reductions in 10-m sprint time were strongly associated with reductions in zigzag dribbling time ($r = 0.71$). Taken together, these findings indicate that appropriately periodized plyometric training may enhance not only explosive physical performance but also selected technical soccer skills, particularly when incorporated into regular training without increasing total training duration.

The improvement observed in shooting accuracy is consistent with previous research demonstrating that plyometric training can positively influence kicking-related outcomes in soccer. Alkhawaldeh and Shihab reported that a plyometric exercise program improved kinetic energy, selected kinematic variables, and shooting accuracy among football players younger than 17 years, providing direct support for the possibility that gains in neuromuscular capacity can transfer to more precise technical execution (31). Similarly, Sedano and colleagues found improvements in explosive strength, acceleration capacity, and kicking speed following plyometric training in young elite soccer players (28), while Rubley and colleagues demonstrated improvements in power and kicking distance among adolescent female soccer players (29). Although kicking speed and distance are not identical to accuracy, these findings collectively suggest that greater lower-limb power can improve important mechanical characteristics of the kicking action. The present results extend this literature by indicating that increased explosive capacity does not necessarily occur at the expense of accuracy; rather, under appropriate conditions, the two may improve concurrently.

A plausible explanation for the shooting findings can be derived from the biomechanics of the soccer instep kick. Effective kicking requires a coordinated transfer of force from the supporting leg and trunk through the pelvis and into the kicking limb, followed by precise foot-to-ball contact. The supporting limb must provide sufficient stability to permit rapid rotational and segmental movements while minimizing unnecessary displacement. Kellis and Katis emphasized the complex biomechanical organization of the instep kick and the importance of coordinated segmental actions in determining kicking performance (23). Likewise, combined strength and kick-coordination training has been shown to influence soccer kick biomechanics, suggesting that increased force-production capacity can become functionally useful when integrated within an established motor pattern (24). Training approaches intended to improve kick performance therefore commonly emphasize both power production and movement coordination (25). Plyometric training may contribute to this process by improving rapid force development, lower-extremity stiffness, reactive strength, and neuromuscular coordination, thereby providing a more stable mechanical base from which the kicking action can be performed (3, 26).

The significant increase in countermovement jump performance provides additional support for this interpretation. Jump height increased substantially in the plyometric group, and the change in countermovement jump was positively correlated with the improvement in shooting accuracy. Plyometric training is well established as an effective method for improving explosive lower-limb power, with meta-analytic evidence demonstrating significant improvements in vertical jump height (4). Similar benefits have been documented in youth soccer populations, where plyometric interventions have improved jumping and other explosive actions (12, 17, 19). Short-term high-intensity plyometric training has also been shown to enhance strength, power, and agility in male soccer players (16). The moderate-to-strong relationship observed between changes in countermovement jump and shooting accuracy in the present study is therefore consistent with the concept that improvements in explosive neuromuscular capacity may provide a physical foundation for better technical execution. However, because these correlations were calculated using the pooled sample and group allocation influenced both physical and technical changes, they should be interpreted as supportive rather than causal evidence.

The age and developmental characteristics of the participants may also help explain why improved power was accompanied by improved shooting accuracy. The participants were aged 17–20 years and had several years of organized soccer experience, meaning that their fundamental kicking patterns were likely more consolidated than those of prepubertal or inexperienced players. The youth physical development model emphasizes that responses to training should be understood in relation to maturation, training age, and the developmental stage of the athlete (8). Evidence also suggests that biological maturation influences responsiveness to plyometric training, particularly in agility-related adaptations (13). Plyometric interventions have been effective in prepubescent and preadolescent soccer players (10, 11), but the manner in which greater force-production capacity is integrated into technical performance may vary across development. Recent research has similarly identified age-related differences in jumping, sprinting, and force-production capacities in young soccer players (2). In late-adolescent players with comparatively stable movement patterns, additional power may therefore be incorporated into existing technical coordination without introducing excessive movement variability.

The significant improvement in zigzag dribbling performance also accords with the known effects of plyometric training on sprinting, acceleration, agility, and change-of-direction capacity. Plyometric training improves the ability to rapidly generate and absorb force during brief ground contacts, qualities that are highly relevant when players repeatedly accelerate, decelerate, and redirect the body while controlling the ball. Meta-analytic findings indicate that plyometric training can improve sprint performance (6), and additional meta-analytical evidence supports beneficial effects on speed-related parameters (7). In junior soccer players, in-season plyometric training has improved repeated change-of-direction and sprint performance (18), while Thomas and colleagues observed improvements in both muscular power and agility following different plyometric techniques in youth players (14). Longer-duration plyometric programs have similarly enhanced explosive power and agility in young soccer players (15). These adaptations are highly relevant to zigzag dribbling, because faster movement through a constrained course requires repeated forceful propulsion, effective braking, rapid redirection of the center of mass, and maintenance of postural control.

The strong association between changes in 10-m sprint performance and zigzag dribbling time further supports this interpretation. Players who demonstrated greater reductions in short-sprint time also tended to show greater reductions in dribbling time. Sprint acceleration over short distances is especially dependent on horizontal force production, rapid motor-unit recruitment, and efficient ground-force application, all of which can be stimulated through appropriately selected plyometric exercises. Research in soccer has repeatedly demonstrated improvements in sprint and acceleration-related performance after plyometric or combined strength-power programs (18-20). In addition, 12 weeks of plyometric training has been associated with greater lower-limb explosive strength among adolescent athletes (22). The current findings therefore suggest that gains in acceleration capacity may facilitate faster movement between successive ball contacts, allowing players to negotiate directional changes in less time while maintaining sufficient technical control.

Nevertheless, the magnitude of improvement in dribbling was smaller than that observed for shooting accuracy. The effect size for shooting was $\eta p^2 = 0.33$, compared with $\eta p^2 = 0.24$ for zigzag dribbling. This difference may reflect the distinct motor requirements of the two skills. Shooting is a relatively discrete action in which a single coordinated explosive sequence culminates in ball contact. Consequently, improvements in force production, limb stability, and rate of force development may transfer relatively directly to execution. Dribbling, in contrast, is a continuous perceptual-motor task involving repeated contacts with the ball, continuous adjustment of stride characteristics, changes in direction, and regulation of movement speed. Research has demonstrated that physical fitness contributes to ball-control performance in young soccer players, but ball control cannot be explained by physical capacity alone (1). Technical proficiency, coordination, visual information processing, and anticipatory behavior also influence dribbling performance. Therefore, a predominantly neuromuscular intervention would be expected to improve the physical component of dribbling without necessarily affecting all of its perceptual and technical determinants.

The findings also support the broader concept that physical conditioning and soccer skill should not always be regarded as separate training domains. Recent research has increasingly examined integrated training models intended to simultaneously improve physical and football-specific performance. For example, small-sided games combined with plyometric training have been investigated for their effects on muscular power, agility, and football skills (32).

Other neuromuscular approaches, including Pilates-based interventions, have also been examined in relation to both physical and technical soccer performance (33). The present study contributes to this evolving perspective because the plyometric program replaced low-intensity tactical activity rather than being added to the overall weekly workload. Consequently, the observed improvements cannot readily be attributed to a greater quantity of training. This finding has considerable applied value because coaches frequently face restrictions on total available training time and must seek interventions that improve multiple performance components simultaneously.

The lack of a significant between-group effect for maximal oxygen uptake provides further insight into the specificity of the intervention. Plyometric training is principally characterized by brief, high-intensity actions and therefore targets neuromuscular and anaerobic qualities rather than central aerobic adaptations. The absence of a meaningful VO2max change, together with substantial improvements in jump and sprint measures, indicates that the intervention produced the intended power-oriented adaptation. This pattern is consistent with systematic evidence demonstrating that plyometric training primarily improves explosive fitness qualities in team-sport athletes (5). It also reinforces the interpretation that improved shooting and dribbling were more likely related to neuromuscular changes than to greater aerobic fitness or general fatigue resistance. The capacity to improve explosive performance without requiring additional overall training time is particularly relevant in young athletes, for whom resistance and power training should be carefully integrated within a comprehensive long-term development program (9).

The present findings may also be understood in relation to neuromuscular timing. Soccer actions are typically performed within very short temporal windows, and producing greater force is useful only when that force can be expressed rapidly enough to influence the movement. Emerging wearable-sensor research has highlighted the importance of neuromuscular latency and the potential strength–timing trade-off in soccer performance (27). Plyometric exercises repeatedly expose athletes to rapid eccentric-concentric transitions and short ground-contact periods, potentially improving not merely maximum force capacity but the timing with which force is expressed. Such adaptations could contribute to faster stabilization of the support limb during shooting and more rapid force application during acceleration and directional changes. Evidence from other sports also demonstrates the broader relevance of plyometrics to agility and athletic proficiency (21). Therefore, the technical benefits observed in the present study may reflect not simply "stronger legs," but more efficient coordination between force magnitude, force timing, and task-specific movement control.

Overall, the present results extend previous evidence by demonstrating that an 8-week periodized plyometric intervention can produce concurrent improvements in explosive neuromuscular qualities and selected technical skills among late-adolescent male soccer players. Previous research has firmly established beneficial effects of plyometric training on jump ability, sprinting, agility, and power (4, 5, 12), while soccer-specific investigations have documented improvements in kicking speed, kicking distance, and shooting-related characteristics (28, 29, 31). The present study advances this body of work by simultaneously examining shooting accuracy and ball control under a matched-volume active-control design. The larger effect observed for shooting compared with dribbling further suggests that transfer may depend on the structural correspondence between the physical adaptation and the technical skill. Accordingly, plyometric training appears particularly effective for technical actions with a substantial explosive component, although its contribution to more complex continuous skills is likely to operate alongside rather than replace technical and perceptual training.

Several limitations should be considered when interpreting the findings. First, the sample consisted of only 24 male soccer players aged 17–20 years, limiting the statistical precision and generalizability of the findings to female players, younger developmental groups, older players, or athletes competing at substantially different performance levels. Second, shooting accuracy and ball control were assessed using standardized closed-skill tests rather than under competitive match conditions, meaning that the results represent technical capacity in a controlled environment rather than actual decision-dependent performance against opponents. Third, the shooting test had limited measurement precision, and the observed adjusted

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E-ISSN: 2981-2569

between-group difference was close to the estimated minimal detectable change, which warrants caution regarding the magnitude of individual improvement. Fourth, the intervention lasted eight weeks and did not include a follow-up assessment; therefore, the persistence of the observed improvements after cessation or reduction of plyometric training remains unknown. Fifth, although correlations between changes in neuromuscular and technical variables were informative, they were calculated using the pooled sample, and group allocation simultaneously influenced both sets of outcomes. These associations therefore cannot demonstrate that improvements in power directly caused improvements in technical performance.

Future studies should recruit larger and more diverse samples and examine whether age, biological maturation, sex, playing position, initial training status, and competitive level moderate the technical response to plyometric training. Longer interventions with post-intervention follow-up assessments would help determine the minimum effective training dose and the persistence of technical adaptations. Future investigations should also evaluate shooting performance using simultaneous measurements of accuracy, ball velocity, foot velocity, ground-reaction forces, and lower-limb muscle activation so that changes in force production can be distinguished from improvements in coordination and movement consistency. Motion analysis and surface electromyography could clarify how adaptations in the support leg, pelvis, and kicking limb contribute to improved execution. For ball control, future studies should incorporate reactive agility tasks, opponent pressure, small-sided games, and match-based video analysis to determine whether improvements observed in standardized dribbling tests transfer to open and unpredictable situations. Experimental designs comparing vertical, horizontal, unilateral, bilateral, and multidirectional plyometric programs would also clarify which exercise characteristics demonstrate the greatest correspondence with different soccer skills.

Coaches and strength and conditioning practitioners may consider integrating short, periodized plyometric blocks into routine soccer training when the objective is to improve explosive physical capacity together with selected technical outcomes. Plyometric exercises should be introduced progressively, beginning with controlled landing mechanics and lower-intensity bilateral activities before advancing toward higher-intensity unilateral, horizontal, reactive, and multidirectional exercises. Sessions should preferably be undertaken when players are relatively non-fatigued so that movement quality and landing control can be maintained. The findings also suggest that plyometric training can replace a limited portion of lower-intensity conditioning or tactical activity rather than simply being added to the existing workload, thereby reducing unnecessary increases in total training volume. However, plyometric training should complement rather than replace soccer-specific technical practice. Coaches should continue to provide substantial shooting, dribbling, passing, and decision-making practice, while using plyometric training to enhance the neuromuscular qualities that support the efficient execution of these skills.

Authors' Contributions

All authors contributed substantially to the study and to manuscript development, and all approved the final version.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

The authors thank the participating centers, clinicians, adolescents, and guardians who made the study possible.

Declaration of Interest

The authors report no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics Considerations

The study placed a high emphasis on ethical considerations. Informed consent obtained from all participants, ensuring they are fully aware of the nature of the study and their role in it. Confidentiality strictly maintained, with data anonymized to protect individual privacy. The study adhered to the ethical guidelines for research with human subjects as outlined in the Declaration of Helsinki.

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E-ISSN: 2981-2569