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Incorporating Squats into Warm-Up Optimizes Sprint, Jump, and Agility in Young Soccer Players

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Abstract

This study investigated how adding squat exercises to the end of warm-ups affects sprinting, jumping, agility, and aerobic fitness in youth soccer players. Twenty-four male U17 players were split into two groups: one performed squats (experimental) and the other did rondo drills (control) for nine weeks. The squat group trained twice a week, doing 3–4 sets of 4–12 reps at increasing intensity (50–85% of 1-RM). After the intervention, the squat group showed significant gains in sprint speed (10 m: –3.8%; 30 m: –2.7%), jumping power (SJ: +6.8%; CMJ: +7.2%; SLJ: +3.8%; 5JT: +3.6%), and agility (–2.8%), while aerobic capacity changed little (+3.4%). The control group showed no improvement. Overall, integrating brief, progressive squat exercises at the end of warm-ups twice weekly led to clear improvements in explosive and agility performance, with minimal effect on endurance.

Keywords: soccer; warm-up; squats; speed; agility

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1. Introduction

Modern soccer demands that players perform repeated explosive actions, such as sprints, jumps, changes of direction, and physical duels [1]. These qualities are important for soccer performance, particularly during decisive phases of a match, where speed and power often determine the outcome [2]. In this context, warm-up represents an essential component of athletic preparation, aimed at reducing injury risk while optimizing immediate performance [3–5].

Traditionally, warm-ups include a general phase (light jogging, joint mobility) and a specific phase involving ball exercises [6]. Many coaches prefer to include a rondo in the final stage of the warm-up, as it stimulates reactivity, coordination, and passing speed under pressure [7–9]. This drill also enhances decision-making and perception-action coupling, providing a dynamic and engaging warm-up that mimics match demands [7]. However, these approaches may be limited in terms of neuromuscular activation, especially for preparing players for explosive efforts. Recently, activation strategies have been proposed, which involve integrating strength or power exercises into the final phase of the warm-up to exploit the post-activation performance enhancement (PAPE) phenomenon, characterized by transient improvements in muscular performance following a conditioning exercise [10,11].

Among these strategies, squat exercises are particularly relevant, as they target the main muscles involved in jumping and sprinting tasks [12,13]. The squat is a fundamental multi-joint movement for developing lower-limb power and explosive strength, qualities directly associated with soccer-specific actions, including short-distance sprints, vertical and horizontal jumps, and agility-based

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movements [14,15]. Although resistance training and plyometric programs have been extensively studied in soccer [16], the strategic integration of squat exercises into the final phase of warm-up remains underexplored, especially in youth players.

Previous studies indicate that incorporating heavy or explosive squats can enhance sprint and jump performance in trained athletes [14,17]. However, most of these studies were conducted under specific experimental conditions, sometimes far removed from the real context of collective soccer warm-ups. In youth soccer players, evidence remains limited and inconsistent. Some studies suggest that squat-induced activation can improve speed and explosive strength [17,18], while others report no significant effects, potentially due to differences in load, player experience, or recovery intervals[19].

Therefore, it is essential to assess the practical effectiveness of integrating squat exercises into the final phase of warm-up compared to traditional technical drills, such as the widely used "rondo". The aim of this study was to examine the long-term effects of including squat exercises into the final phase of the warm-up on sprinting, jumping, agility, and aerobic performance in young soccer players. We hypothesized that a squat-based warm-up would lead to greater improvements in sprint, jump, and agility performance than a rondo-based warm-up, while no significant difference would be observed in aerobic performance between the two programs. By comparing these two approaches over a nine-week intervention, this study also seeks to provide practical recommendations for optimizing warm-up strategies in youth soccer training.

2. Material and Methods

2.1. Participants

Before recruiting participants, a sample size calculation was performed using G*Power software (version 3.1.9.7, University of Kiel, Germany) based on a repeated-measures ANOVA design with within–between interaction [20]. Effect sizes used for the calculation were drawn from preliminary data on the effects of squat exercises versus rondo drills on sprint and jump performance in young male soccer players [21]. The analysis indicated that a minimum of 24 participants (effect size f = 0.35, statistical power = 82%) was required to detect significant group × time interactions, assuming a Type I error rate of 0.05 and a Type II error rate of 0.18. Ideally, a few more participants would have been recruited to account for possible dropouts; however, all 24 male youth soccer players (under-17 category) from the same team who were recruited finished the study, so there were no dropouts and the necessary statistical power was maintained. To account for potential dropout, 24 male youth soccer players (under-17 category) from the same regional training academy were recruited. Participants were classified according to their playing positions (central defender, full-back, midfielder, and forward), with goalkeepers excluded due to their distinct training regimens. For their regular training, players participated in five training sessions and in one match per week. To minimize any bias associated with position-specific physical demands, player positions were carefully considered during randomization, ensuring that each group (experimental and control) had an equal representation of positions. Players were then randomly assigned to the experimental group: EG (n = 12; age = 17.1 ± 0.6 years, height = 174.3 ± 5.8 cm, body mass = 66.5 ± 6.7 kg, soccer experience = 6.2 ± 1.1 years) or the control group: CG (n = 12; age = 17.0 ± 0.7 years, height = 173.6 ± 6.1 cm, body mass = 65.8 ± 7.1 kg, soccer experience = 6.0 ± 1.3 years) using a coin toss.

Consistently with a random assignment of two groups, no significant differences between groups were found at baseline for age, height, body mass, and training experience ($p > 0.05$ by independent t-test). The inclusion criteria were: (i) all participants were members of the same team; (ii) none of the players had experienced any illness or injury during the eight weeks preceding and throughout the experimental period; (iii) have previous experience with the squat exercise (iv) no physical or cognitive disorders were reported; and (v) participants consistently attended training sessions.

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To ensure fair and unbiased allocation, the randomization process was overseen by a blinded assessor not involved in testing. All participants and their legal guardians provided written informed consent, and the study was conducted in accordance with the Declaration of Helsinki and approved by the institutional ethics committee of the High Institute of Sports and Physical Education in Kef (ISSEPK-0036/2024, 01 December 2024). Table 1 presents baseline characteristics of the participants.

Table 1. Baseline characteristics of the participants (Mean ± SD).

Variable	EG (n = 12)	CG (n = 12)	p-value
Age (years)	17.1 ± 0.6	17.0 ± 0.7	0.72
Height (cm)	174.3 ± 5.8	173.6 ± 6.1	0.81
Body mass (kg)	66.5 ± 6.7	65.8 ± 7.1	0.84
Training experience (years)	6.2 ± 1.1	6.0 ± 1.3	0.69

EG = Experimental Group, CG = Control Group, kg = kilograms, cm = centimeters, n = number of participants, Data are presented as mean ± standard deviation.

Experimental Procedure

The study was conducted over an eleven-week period, including a pre-test week, nine weeks of training, and a post-test week. Prior to the intervention, participants' anthropometric characteristics and The one-repetition maximum (1-RM) was assessed. The 1-RM was estimated using a submaximal squat test, in which participants performed progressively heavier loads until reaching a weight they could lift for 4–6 repetitions with correct technique, then calculated using the Brzycki formula. This gave the progressive load prescription a secure and trustworthy starting point. During the intervention period, the EG added targeted squat exercises at the end of the warm-up twice weekly to induce a post-activation potentiation (PAP) effect and enhance neuromuscular readiness [10,22]. The CG, under the same time conditions, performed a 4v2 rondo drill [23] focused on ball retention and reactivity, without the execution of any resistance training exercise. Both groups then completed the same regular soccer training program, ensuring equal overall training volume and load. This design isolated the specific contribution of each warm-up modality to performance adaptations.

Performance assessments were conducted before and after the intervention using validated tests for youth soccer players: 10 m and 30 m sprints, standing long jump (SLJ), five-jump test (5JT), squat jump (SJ), countermovement jump (CMJ), T-half agility test, and the VAMEVAL test. Each participant completed two maximal trials per test (10 m, 30 m, SLJ, 5JT, SJ, CMJ) with three minutes of passive recovery, and the best performance was recorded. Testing sessions were standardized, with consistent verbal encouragement, and all measurements were taken on the same synthetic pitch between 16:30 and 17:00 to control for circadian influences [24]. A familiarization session was conducted beforehand to minimize learning effects. Rating of perceived exertion (RPE) was collected after each intervention to assess internal intensity [25].

- Training Protocol

The nine-week training program consisted of five weekly sessions during the competitive season, with each session beginning with a standardized warm-up divided into three phases: a 8-minute general phase including light jogging, joint mobility exercises, and dynamic stretching; a 8-minute specific phase with coordination and acceleration drills using the ball; and a 10–12 minute final phase consisting of intervention-specific exercises, either squat-based (EG) or rondo-based (CG) (Table 2).

The experimental intervention was performed twice weekly during the final warm-up phase. For the EG, the warm-up included a structured squat protocol integrated into the final phase, aimed at progressively activating the lower limbs and preparing players for explosive actions. Intensity progressed during the course of the nine weeks from 50% to 85% of 1-RM following the principle of progressive overload. Each session included 3–4 sets of 4–12 repetitions at a 2-0-1 tempo (2 seconds eccentric, 0-second pause, 1 second concentric explosive) with 2–3 minutes of rest between sets [26]. In this exercise, the players started from an upright standing position with full extension of the hips and knees, while the barbell was positioned across the upper back at the level of the acromion. They then performed the downward phase until the thighs went below a 90° angle, followed by the upward phase to return to the starting position [27].

To ensure smooth organization and avoid time loss, four squat stations were set up along the sideline of the football pitch. Each station included a barbell and a rack placed at shoulder height, with a distance of two meters between stations. The first four players performed the exercise simultaneously, followed by the next four, and so on, until all participants completed their sets. All players followed the same recovery time between sets to standardize the training conditions.

The CG performed a 4v2 rondo drill emphasizing ball retention and rapid short movements [23], while both groups continued their regular football training to maintain equal overall training volume (Table 3). Participants were instructed to maintain regular sleep patterns and avoid strenuous physical activity the day before testing to minimize fatigue.

Table 2. Description of the intervention program.

Session Component	EG	CG
General warm-up (8 min)	Jogging, mobility, dynamic stretching	Jogging, mobility, dynamic stretching
Specific warm-up (8 min)	Technical drills with the ball	Technical drills with the ball
Final phase (5 min)	3–4 sets × 4–12 reps squats with progressive load (50–85% 1-RM), tempo 2-0-1, 2 min rest between sets	2 × 4–6 min rondo (4v2), 1 min rest
Total session duration	26-28 min	26-28 min

EG = Experimental Group, CG = Control Group, min = minute.

Table 3. Baseline characteristics of the participants (Mean ± SD).

Week	Day	%1-RM	Reps per Set	Sets	Tempo (Eccentric/ Concentric)	Notes
1	Tue, Thu	50%	12	3	2-0-1	Focus on technique, controlled depth
2	Tue, Thu	55%	10	3	2-0-1	Slightly higher intensity
3	Tue, Thu	60%	10	3	2-0-1	Maintain good form, moderate load
4	Tue, Thu	65%	8	3	2-0-1	Emphasize power on concentric phase
5	Tue, Thu	70%	8	3	2-0-1	Full explosive concentric phase
6	Tue, Thu	75%	6	3	2-0-1	Focus on maximal force output

7	Tue, Thu	75%	6	4	2-0-1	Increase volume with extra set
8	Tue, Thu	80%	5	4	2-0-1	High-intensity phase, low reps, explosive
9	Tue, Thu	85%	4	4	2-0-1	Peak phase, emphasis on maximal power

Week = week number, Day = training day, %1-RM = percentage of one-repetition maximum, Reps per Set = repetitions per set, Sets = number of sets,Tue = Tuesday, Thu = Thursday. Tempo notation: Eccentric (down) - Pause - Concentric (up) → e.g., 2-0-1 = 2 sec down, 0 pause, 1 sec up explosive.

- **Rating of Perceived Exertion (RPE)**

The internal training load was assessed immediately after the squat exercises (EG) or rondo drills (CG) performed during the final phase of the warm-up. The Borg CR-10 RPE scale was used to measure the perceived effort associated with each session [25]. This method has been previously shown to be valid and reliable for quantifying internal load in soccer contexts [28]. To ensure accurate responses, all participants were familiarized with the RPE scale prior to the intervention

- Linear sprint

Sprint performance was assessed over 10 m and 30 m on a synthetic grass pitch. Each participant performed two maximal 30-m sprints, with split times recorded at 10 m [29]. To guarantee uniformity and minimize any order effects, all tests were administered to each participant in the same standardized order before and after the intervention. A passive recovery period of three minutes was provided between each sprint to minimize fatigue. Sprint times were recorded using electronic timing gates (Globus, Microgate, Italy) to ensure precision. For data analysis, the fastest 30-m sprint of the three trials was retained. Test reliability was excellent, with an ICC of 0.92 and CV of 2.1% for the 10-m sprint, and an ICC of 0.93 and CV of 1.9% for the 30-m sprint.

- Horizontal Jump

Horizontal jump performance was assessed using the standing long jump (SLJ) and the five-jump test (5JT). In the SLJ, participants jumped forward as far as possible from a standing position with feet together, landing with both feet. In the 5JT, participants performed five consecutive horizontal jumps, emphasizing maximal distance and proper landing mechanics. Two trials were conducted for each test with three minutes of passive recovery, and the best performance was recorded. Reliability indices were: SLJ – ICC = 0.88, CV = 3.0%; 5JT – ICC = 0.89, CV = 2.7%.

- **Vertical Jump**

Vertical jump performance was evaluated using the squat jump (SJ) and countermovement jump (CMJ) [30]. Prior to the assessment, participants executed 2–3 self-paced submaximal CMJs and SJs to familiarize themselves with the testing procedures and to ensure adequate specific warm-up. During all trials, players were instructed to place their hands on their hips to eliminate the contribution of arm swing and minimize coordination effects, thereby isolating lower-limb extensor performance [30].

For the SJ, participants adopted a static semi-squat position with knees flexed at approximately 90° and performed a vertical jump without any preparatory movement. For the CMJ, they completed a rapid downward movement immediately followed by a forceful upward jump. Each participant performed two maximal attempts for both SJ and CMJ, with approximately two minutes of passive recovery between trials. The best performance was retained for analysis. The tests demonstrated high reliability (SJ: ICC = 0.90, CV = 2.5%; CMJ: ICC = 0.91, CV = 2.3%).

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- Agility

Agility was assessed using the T-half agility test, which measures multidirectional change-of-direction ability [31]. Participants sprinted, shuffled, and backpedaled along a T-shaped course as quickly as possible. Two trials were performed with three minutes of passive recovery, and the best trial was retained for analysis. Reliability for the test was ICC = 0.87, CV = 2.8%.

- Aerobic Endurance

Aerobic capacity was assessed using the VAMEVAL test, which provides a reliable measure of maximal aerobic speed (MAS) [32]. The Vameval test was performed on a 200-m running track. The course was marked with ten cones placed at 20-m intervals, and participants followed a pre-programmed auditory signal (beep) to guide their running pace. The test began at a speed of 8 $km \cdot h^{-1}$, which was increased by 0.5 $km \cdot h^{-1}$ every minute until the participant reached exhaustion. Participants were responsible for maintaining their running pattern between the cones. The test ended when a participant was unable to reach the next cone in time with the beep on two consecutive occasions or voluntarily stopped due to fatigue [32]. The highest speed successfully maintained before exhaustion was recorded as the MAS.

2.2. Statistical Analysis

All data were analyzed using SPSS version 28.0 (IBM, Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation (M ± SD). Normality of distribution was verified using the Shapiro–Wilk test, and homogeneity of variance was checked with Levene's test. To examine the effects of the intervention, a mixed analysis of variance (ANOVA) was performed for each physical performance variable, including time (pre vs. post) as within-subject factor and group (EG and CG) as between-subject factor. When significant main effects or interactions were detected, Bonferroni post hoc tests were applied to identify pairwise differences between pre- and post-test values within and between groups.

Effect sizes were calculated using partial eta squared ($\eta^2 p$) for the ANOVA and interpreted according to Cohen's guidelines as small (0.01), medium (0.06), or large (0.14) [33]. Additionally, within-group changes were quantified using percentage change (Δ%) and Cohen's d, with effect sizes classified as trivial (<0.2), small (0.2–0.5), moderate (0.5–0.8), or large (>0.8) [34].

Rating of Perceived Exertion (RPE), was analyzed using the non-parametric Mann–Whitney U test for each training session, comparing the experimental (EG) and control (CG) groups.

Statistical significance was set at $p < 0.05$.

3. Results

RPE scores were recorded across 18 training sessions. Mann–Whitney U tests showed that RPE values were generally similar between the experimental and control groups throughout the intervention (Table 4). For all other sessions, ($p<0.05$), indicating comparable perceived effort between groups. Figure 1 illustrates the weekly RPE evolution, showing parallel trends between groups.

Table 4. Mean (±SD) Rating of Perceived Exertion (RPE) Scores by Session for Experimental and Control Groups.

Session	U	p-value
S1	66	0.66
S2	60	0.39
S3	54	0.18
S4	50.5	0.13

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S5	66	0.75
S6	54	0.27
S7	58	0.34
S8	60	0.39
S9	63	0.56
S10	66	0.68
S11	54	0.18
S12	60	0.41
S13	66	0.66
S14	66	0.68
S15	60	0.42
S16	66	0.68
S17	50	0.13
S18	62	0.48

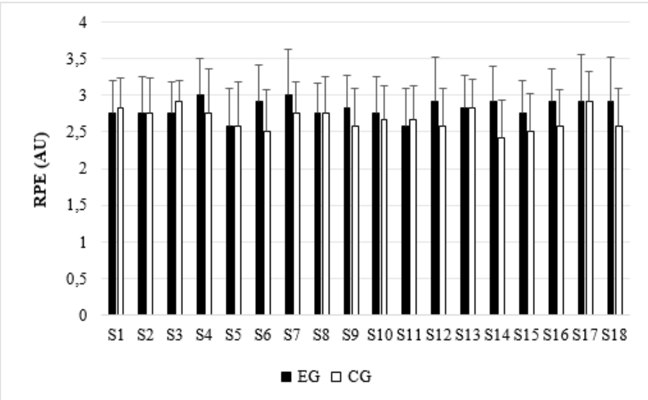

Figure 1. Weekly RPE Scores Over 9 Weeks (Post Warm-Up).

Pre- and post-intervention comparisons revealed significant improvements in the experimental group (EG) across most physical performance tests, whereas the control group (CG) showed no significative changes. Significant differences were observed in the 10-m sprint ($p < 0.001$), 30-m sprint ($p < 0.001$), squat jump ($p < 0.001$), countermovement jump ($p < 0.001$), standing long jump ($p = 0.003$), 5-jump test ($p < 0.001$), and T-half agility test ($p < 0.001$), indicating notable gains in speed, power, and agility in the experimental group.

In contrast, no significant changes were found for the VAMEVAL test ($p > 0.05$), suggesting similar aerobic endurance performance between groups. The control group did not show significant improvements for any variable (all $p > 0.05$). Mean values, percentage changes, and effect sizes are detailed in Table 5.

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Table 5. Pre- and Post-Test Results of Physical Performance.

Variable	Group	Pre-test	Post-test	Δ%	Cohen's d	Effect
Sprint 10 m (s)	EG	1.81 ± 0.04	1.77 ± 0.05	-2.21	1.0	Large
	CG	1.78 ± 0.06	1.79 ± 0.06	0.56	0.16	Trivial
Sprint 30 m (s)	EG	4.37 ± 0.12	4.30 ± 0.11	-1.60	0.58	Medium
	CG	4.33 ± 0.11	4.32 ± 0.09	-0.23	0.09	Trivial
SJ (cm)	EG	32.75 ± 2.63	36 ± 2.13	9.92	1.23	Large
	CG	34 ± 3.13	33.9 ± 2.19	-0.29	0.03	Trivial
CMJ (cm)	EG	35.6 ± 2.34	39.9 ± 1.72	12.08	1.83	Large
	CG	36 ± 2.33	36.08 ± 1.83	0.22	0.03	Trivial
SLJ (m)	EG	2.24 ± 0.2	2.4 ± 0.13	7.14	0.8	Large
	CG	2.25 ± 1.88	2.26 ± 0.12	0.44	0.05	Trivial
5JT (m)	EG	11.63 ± 0.83	11.9 ± 0.84	2.33	0.32	Small
	CG	11.99 ± 0.94	12.04 ± 0.86	0.42	0.05	Trivial
T-half agility (s)	EG	5.66 ± 0.25	5.58 ± 0.24	-1.41	0.32	Small
	CG	5.77 ± 0.25	5.76 ± 0.24	-0.17	0.04	Trivial
VAMEVAL (km/h)	EG	17.25 ± 0.91	17.41 ± 0.84	0.93	0.18	Trivial
	CG	17.29 ± 0.72	17.33 ± 0.74	0.23	0.06	Trivial

Δ% = percentage change from pre- to post-test, Cohen's d interpreted as. trivial (0-0.20), small (>0.20-0.50),Medium (>0.50-0.80), and large (>0.80). EG = Experimental Group; CG = Control Group; SJ = Squat Jump; CMJ = Countermovement Jump; SLJ = Standing Long Jump; 5JT = 5-Jump Test. m = meters, ($km{\cdot}h^{-1}$) = kilometers per hour, s = seconds, cm = centimeters.

The results presented in Table 6 show that the two-way ANOVA (Group × Time) revealed significant main effects of time for most physical performance variables, except for the VAMEVAL test. These findings indicate an overall improvement in performance over time, particularly in sprint, jump, and agility tests. No significant main effect of group was observed, suggesting that participants from the different groups exhibited comparable performance levels.

Conversely, significant Group × Time interaction effects were found for several tests, indicating that performance improvements varied between groups. These interactions were mainly observed in speed, explosive power, and agility measures, while no differential changes were detected for aerobic endurance as assessed by the VAMEVAL test.

Table 6. Two-way ANOVA results (Group × Time) for physical performance variables.

Variable	Main effect of the time		Main effect of the group		Interaction effect	
	F	η2	F	η2	F	η2
10-m sprint (s)	17.17***	0.48	0.43	0.02	7.1*	0.24
30-m sprint (s)	28.15***	0.56	0.11	0.05	14.61**	0.39
Squat jump (cm)	45.38***	0.67	0.17	0.08	50.28***	0.69
Countermovement jump (cm)	84.98***	0.79	4.59	0.17	78.57	0.78
Standing long jump (cm)	11***	0.33	1.66	0.07	7.36*	0.25
5-jump test (m)	35.14***	0.61	0.49	0.02	16.45***	0.42
T-half agility test (s)	42.01***	0.65	2.67	0.19	28.95***	0.56
VAMEVAL (km·h⁻¹)	1.47	0.06	0.004	0.000	0.53	0.02

p = significance of interaction, s = seconds; cm = centimeters; m = meters; $km \cdot h^{-1}$ = kilometers per hour.

4. Discussion

The present study investigated the effects of integrating squat exercises into the final phase of warm-up on explosive strength, sprint performance, agility, and aerobic capacity in youth soccer players over a nine-week intervention. The main findings revealed that players in the EG demonstrated significant improvements in short sprint performance (10 and 30 m), vertical and horizontal jump tests, and agility performance, with effect sizes ranging from moderate to large. In contrast, no significant effect was observed on aerobic capacity, with only a small effect size noted.

Our results showed that the experimental group improved significantly in the 10 m and 30 m sprint tests. These findings suggest that the inclusion of squat exercises during warm-up enhances neuromuscular readiness, particularly the ability to generate explosive force over short distances [27,35–38]. Similar results were reported by [39] and who found that lower-limb resistance training improved sprint performance in soccer players. The large effect observed in the 10 m sprint highlights the role of squats in improving acceleration capacity, which is critical for match-related actions such as pressing, defensive recovery, and attacking runs [40]. These findings are also supported by [41], who emphasized the post-activation performance enhancement (PAPE) phenomenon, showing that high-intensity contractions can transiently improve subsequent explosive movements.

Significant gains were observed in jump performance, with the squat jump and countermovement jump showing the greatest improvements. These results are consistent with previous research demonstrating that squats effectively enhance lower-limb power output [42]. Horizontal jump performance also improved, as reflected in the standing long jump and five-jump test. The transfer of squat training adaptations to both vertical and horizontal force production suggests improved neuromuscular coordination and intermuscular efficiency [43]. Additionally, Díaz-Hidalgo et al. (2024) reported that explosive strength exercises can acutely enhance sprint and jump performance in soccer players, particularly when incorporated into warm-up routines, supporting the ecological validity of our intervention [44].

The T-half agility test performance improved significantly in the experimental group. Agility is highly dependent on both acceleration and deceleration capacities, which are influenced by lower-limb strength. The present findings align with those of Aytac et al. (2024) and Darko et al. (2025), who emphasized the importance of strength training in enhancing change-of-direction performance. Furthermore, the inclusion of PAPE-oriented exercises like squats can improve reactive strength and rapid force production during multidirectional movements, which are essential for soccer-specific actions [45–47].

No significant changes were found in VAMEVAL test performance, indicating that squat-based warm-up primarily targets neuromuscular and explosive capacities rather than aerobic fitness. This limited impact on aerobic performance can be explained by the nature, duration, and intensity of the squat intervention. This outcome is expected, as strength-oriented protocols do not significantly stimulate the cardiorespiratory system [48]. Aerobic adaptations generally require continuous or interval training of longer duration and higher cardiovascular demand [49]. These findings are consistent with previous evidence showing that strength or power-based warm-up activities mainly elicit acute potentiation effects, improving explosive actions without significantly influencing aerobic parameters [48]. This finding is consistent with previous studies highlighting the specificity of training adaptations: resistance exercises improve power and sprint-related qualities but have limited effects on endurance performance [50].

Practical Applications

From a practical perspective, the findings highlight the effectiveness of integrating squat exercises into the warm-up routine. The improvements observed in explosive strength, sprint speed, and agility indicate that a short, well-structured squat protocol can optimize players' readiness before training and competition. Coaches working with youth soccer players may consider adopting squat-based activation, especially during the pre-competition warm-up, to maximize immediate performance outcomes and long-term neuromuscular adaptations. Importantly, the use of progressive load (50–85% 1-RM) with controlled tempo and adequate recovery appears to be crucial for eliciting these benefits. This supports recommendations regarding the optimal structure of warm-up interventions to exploit PAPE effects [51,52].

Limitations and Future Directions

Despite its promising findings, the study presents some limitations. First, the relatively small sample size (n = 24) may restrict the generalizability of results. Second, the intervention period was limited to nine weeks; longer-term studies could provide further insights into the sustainability of performance gains. Third, while the study focused on physical performance measures, additional psychophysiological variables such as perceived exertion, physical enjoyment, and motivation could provide a more comprehensive understanding of the impact of squat-based warm-up. Future research may also examine the combined effects of squat exercises with other neuromuscular activation strategies (e.g., plyometrics or resisted sprints) to determine the most effective warm-up modalities for soccer players. Integrating technical drills with strength exercises may further enhance transfer to game-specific scenarios [53,54].

5. Conclusions of the Discussion

In summary, the present study demonstrated that incorporating squat exercises into the final phase of warm-up produced moderate to large improvements in sprint performance, jump ability, and agility, while only a small effect was observed in aerobic capacity. These results confirm the value of squat-based activation as an effective, practical, and time-efficient strategy to enhance performance in youth soccer players. Moreover, the findings are supported by current literature on PAPE, neuromuscular conditioning, and sport-specific warm-up design, emphasizing the importance of evidence-based interventions for optimizing young athletes' performance.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the institutional ethics committee of the High Institute of Sports and Physical Education in Kef (ISSEPK-0036/2024, 01 December 2024).

Consent for publication: All participants provided consent for anonymous data use for research purposes and publications. All authors approved of the final version to be published and agree to be accountable for any part of the work.

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Availability of data and materials: The data that support the findings of this study are openly available upon request from the corresponding author.

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