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Original Article

The effect of a 15-min transition period after warm-up on the performance of male semi-professional soccer players

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Abstract
Introduction: Warm-up is essential for optimizing athletic performance in both individual and team sports, though its effects tend to diminish or disappear after a certain period of time. However, in soccer, competition rules mandate a 15-min transition period before the match begins. **Purpose:** This study investigated the effect of this transitional period on maintaining performance in various physical abilities, including hip flexion range of motion (ROM), countermovement jump (CMJ),10 m and 30 m sprint speed, change of direction (COD) speed (measured via the Arrowhead Agility Test (AAT) for both directions: AATR for right and AATL for left), and repeated sprint ability (RSA). **Method:** Sixteen male semi-professional soccer players participated in the study, performing either a 25-min traditional warm-up (FIELD WU) or a 22-min pre-warm-up exercise program combined with the traditional soccer warm-up (GYM+FIELD WU). **Results:** A two-factor mixed ANOVA analysis ("program" and "time") revealed a significant interaction between the two factors only for the variables of ROM ($p < 0.001$) and CMJ ($p < 0.02$). Additionally, a significant decline in CMJ performance and a tendency toward reduced AATR performance were observed 15 min after completing the GYM+FIELD WU. Similarly, a significant decrease in ROM and AATL, along with a trend toward reduced 30 m sprint performance, was noted following the FIELD WU program in the same time frame. **Conclusion:** The results of this study indicate that the 15-min transitional period following the completion of both the FIELD WU and GYM+FIELD WU has a detrimental effect on the performance of soccer players.
Keywords: recovery period, pre-warm-up actions, flexibility, power, speed, RSA

Introduction

In modern soccer, the game's intensity and pace demand exceptional physical capability, requiring players to maintain a high level of physical fitness to meet these challenges. However, the high intensity of both training and competitive activities also increases the risk of musculoskeletal injuries (Barnes, Archer, Hogg, Bush & Bradley, 2014), particularly in the lower limbs (Ekstrand, Hägglund & Waldén, 2011).

To help players meet these physical demands and reduce the risk of muscular injuries, a well-structured warm-up is essential. It prepares the body for technical, tactical, physical, and mental actions while preserving the energy reserves necessary for peak performance during training and competition (Bizzini et al., 2013).

To achieve the objectives of soccer warm-up training—enhancing performance and reducing injury risk—various programs, such as FIFA 11+ and HarmoKnee, have been introduced in recent years (Arsenis et al., 2020; Bizzini et al., 2013; Daneshjoo et al., 2012). These programs incorporate innovative exercises, performed either with or without equipment, often as part of pre-warm-up routines in the gym before transitioning to the traditional on-field warm-up. Examples include muscle release exercises using foam rollers (FRs), isometric core activation exercises (e.g., planks), balance drills on BOSU balls, dynamic or static mobility stretching, and resistance band strength exercises. These exercises can be performed individually (Healey et al., 2014; Madoni et al., 2018; Wallace et al., 2006) or in combination (Kyranoudis et al., 2021), although their effectiveness varies. Professional and semi-professional teams are required to complete their warm-up at least 15 min before the match begins (Towlson et al., 2013). This interval between the end of the warm-up and the start of the match, known as the transition or recovery period, is a crucial consideration for coaches and fitness professionals because it can influence the effectiveness of the warm-up and, consequently, players' performance (Kilduff et al., 2013a;MacGowan et al., 2015). Prolonged transition periods may reduce or even eliminate the benefits of the warm-up (Silva et al., 2018). Although Bishop (2003b) argues that post-warm-up intervals of up to 20 min do not impair short-duration activities (e.g., vertical jumps (VJs) or sprints lasting under 10 s), other studies present conflicting evidence (Faigenbaum et al.,2010; Galazoulas et al., 2012). For example, Galazoulas et al. (2012) reported declines in VJ performance and 10- and 20-msprint times in elite basketball players just 10 min after completing their warm-up. Similarly, Faigenbaum et al. (2010) observed reduced VJ performance as early as 6 min after a dynamic warm-up. In contrast, Petisco et al. (2019) reported improvements in soccer players'

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jumping and change of direction (COD) performance following a 15-min recovery period that incorporated additional Post-Activation Potentiation (PAP) exercises, compared to a similar warm-up without PAP. Bishop (2003 a, b) also highlights that periods longer than 5 min can restore oxygen levels to pre-warm-up baselines, potentially affecting activities lasting more than 10 s, such as repeated sprints. Similarly, Burnley et al. (2006) found that oxygen levels returned to near baseline levels approximately 14–15 min after intense exercise. Additionally, Mohr, Krustrup, Nybo, Nielsen, and Bangsbo (2004) recorded a decline in sprint performance among professional football players after a 15-min break (e.g., halftime during a match).

The primary factors believed to reduce performance post-warm-up are decreased body temperature and the deactivation of PAP (Faigenbaum et al., 2010; Galazoulas et al., 2012; Mohr et al.,2004; Raccuglia et al., 2016; Racinais & Oksa, 2010; Xenofondos et al., 2010). Raccuglia et al. (2016) report that muscle temperature decreases 15–30 min post-exercise, leading to a general reduction in performance, particularly in high-speed activities (Racinais & Oksa, 2010). Similarly, Mohr et al. (2004) reported that the decline in core and muscle temperature was associated with a reduced sprint capacity. PAP, which is typically induced by high-intensity actions requiring power, strength, and speed, depends on fast-twitch type II muscle fibers (Xenofondos et al., 2010). However, evidence indicates that performance in explosive actions can decline even after brief recovery periods (Chatzopoulos et al., 2007; Faifenbaum et al., 2010; Galazoulas et al., 2012; Golas et al., 2016). Notably, PAP and fatigue can coexist, meaning that shorter recovery times post-warm-up may worsen fatigue (Tillin & Cooke, 2009), while longer breaks may reduce PAP (Xenofondos et al., 2010). Additionally, Blazevich & Babault (2019) suggest that a new approach known as Post-Activation Potentiation Enhancement (PAPE)—which refers to prolonged improvements in muscle force production lasting several min—is influenced by factors such as increased muscle temperature.

This study aims to evaluate soccer players' performance across various metrics 15 min after two warm-up protocols: a traditional field warm-up (FIELD WU) and a combined gym-and-field warm-up (GYM+FIELD WU). The 15-min interval was chosen to align with professional and semi-professional soccer match regulations, which require the warm-up to be completed at least 15 min before the match begins.

Material & methods

Subjects

Sixteen highly trained male amateur (semi-professional) soccer players, with an average age of 22.1 ± 3.2 years, height of 176 ± 7.2 cm, weight of 74.1 ± 7.6 kg, and body mass index (BMI) of 23.7 ± 1.3, participated in this study. Participants were selected using convenience and purposeful sampling methods. Eligibility criteria included being highly trained male amateur soccer players actively competing in the Greek third national league. They trained five times per week for approximately 90 min per session and played one match weekly. All participants were injury-free and had no musculoskeletal issues for at least three months prior to the study. The research was performed one week post-season during the transition phase, with protocol familiarization sessions held on separate days from the main testing. All players were informed about the study's purpose, significance, procedures, and risks, and they provided signed informed consent. The researchers performing the tests were blinded to the participants' assigned groups.Testing was performed in accordance with the principles outlined in the Helsinki Declaration.

Procedures

The entire testing procedure lasted seven days. On Day 1, baseline anthropometric measurements (height, weight, and BMI) and the Yo-Yo Intermittent Recovery Test-2 (Yo-Yo IR2) were performed to determine Maximum Heart Rate (HRmax). Participants were then randomly assigned to four groups (n=4 per group) to ensure optimal protocol adherence control. The randomization process was performed using Excel, where each player was assigned a unique random number generated via the RAND function. The randomized list was then sorted, and players were allocated to groups accordingly. To maintain allocation concealment, the sequence was stored in a separate, hidden sheet until the start of the trials, preventing any influence on group assignment before the study began.

To minimize fatigue, the test battery was divided into two groups:

- **Test Group A**: hip flexion range of motion (ROM), countermovement jump(CMJ)with hands on the waist, and the Repeated Sprint Ability (RSA) test.
- **Test Group B**: 30 m sprint test (with additional measurement at 10 m) and Arrowhead Agility Test (AAT) to the right (AATR) and left (AATL).

Two warm-up protocols were tested:

1. **GYM+FIELD WU**: A combined warm-up consisting of a gym session (approximately 22 min) followed by an on-field warm-up (approximately 25 min).
2. **FIELD WU**: A traditional on-field warm-up only (control program).

Groups alternated protocols on different days in a randomized order (Figure 1). Days 2 and 3 were dedicated to familiarizing participants with the intervention protocols and performing baseline measurements for groups A and B, spaced 48 h apart to minimize carryover effects. On Day 4, 72 h later, the testing sequence began, with Group 1 performing the GYM WU alone, followed by both Groups 1 and 3 completing the FIELD WU together.

After the warm-up, the groups performed Test A, with independent testers collecting ROM and CMJ data, followed by RSA trials. To accommodate the extended duration of the trials and avoid delays, two testers were assigned to measurements, each performing four tests. After a 15-min passive rest period (recovery), participants repeated the tests (REC) in the same order and with the same testers. This sequence was then repeated for Groups 2 and 4. On Day 5, the protocols were reversed for each group, applying Test Group B. The players performed the sprint trials followed by the AAT test. Fifteen min later, the participants repeated the tests (REC) in the same order and with the same testers. On Days 6 and 7, the protocol order from Days 4 and 5 was repeated. Body temperature (Te) was measured pre-warm-up and post-warm-up. Body temperature was measured pre-warm-up and post-15-min recovery using an AEG infrared ear thermometer (FT 4919-Germany). Heart rate was monitored with Polar S810i heart rate monitors (Polar, Finland). The protocol was followed at the same time each day, with independent testers administering each measurement. Measurement days were spaced 72 h apart to allow oxidative stress from soccer-related inflammatory responses to subside (Fatouros et al.,2010). Testing was performed under conditions with an outdoor ambient temperature of 25.5°C ± 1.4°C, relative humidity of 65.8% ± 10.7%, and air movement at 2.3 ± 1.2 m/s.

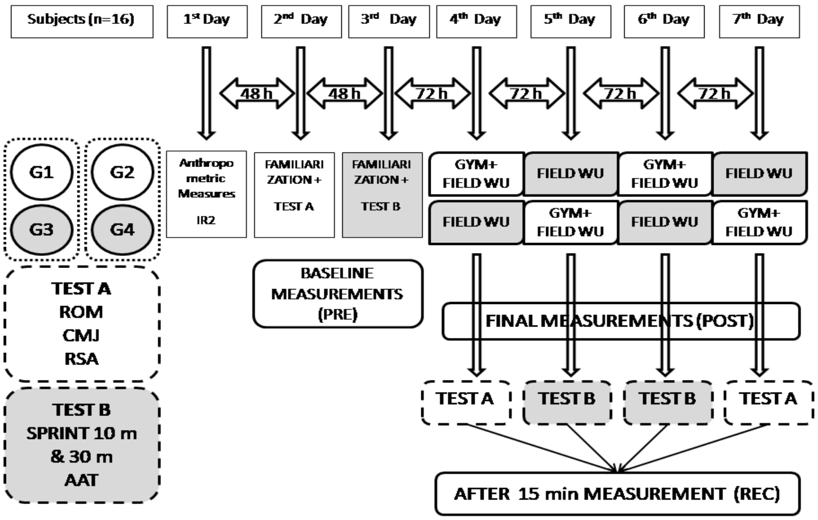


Figure 1. Intervention protocol design

G1, G2, G3, G4: Group 1,2,3,4; ROM: Range of Motion; CMJ: Countermovement Jump; RSA: Repeated Sprint Ability; AAT: Arrowhead Agility Test; GYM WU: Gym Warm-Up; FIELD WU: Field Warm-Up; GYM+FIELD WU: Combined Gym and Field Warm-Up

Warm-up protocols

Tables 1 and 2 present the content and duration of the two warm-up protocols.

Table 1. The content and duration of GYM WU protocol

GYM WU	**Duration: 22 min**		
Foam rollers	Knee flexor muscles Gastrocnemius Knee extensor muscles Adductors–abductors	30 s/leg Break/exercise: 30 s	7 min
Break 30 s			30 s
Static stretching	Knee flexor muscles Gastrocnemius Knee extensor muscles Adductors	10 s/muscle	1 min
Break 30 s			30 s
Plank exercises	Core muscles	20sa-side	2 min
Break 30 s			30 s
Dynamic hurdle passages		5 exercises × 5 reps/leg	2 min
Break 30 s			30 s
Resistance elastic	Knee flexor muscles	15 reps/leg	3 min

bands	Gastrocnemius Knee extensor muscles Peroneus		
Break 30 s			30 s
BOSU: Balance Lifts Semi-squats		15s/leg 30sbreak 10 repetitions 30sbreak 12 repetitions	4 min

Table 2. The content and duration of FIELD WU protocol

FIELD WU	**Duration: 25 min**
Passes in pairs	2min
Break	30 s
Running exercises – waist exercises (skipping, side and crossed steps, zig-zag runs, leg projections, waist turns from standing position, waist rotation with knee lift,…)	3 min 20 s
Dynamic exercises	4 min
Break	30 s
Coordination exercises	3 min 30 s
Break	30 s
Small-Sided Games (SSG) 4v4	4 min
Break	30 s
Technical–tactical exercise	4 min
Break	30 s
Sprints (2 × 8 m in a straight line and 1 × 12 m [4 m forward + 4 m backward + 4 m forward])/20sbreak	~90 s

Physical fitness test battery

Hip flexion ROM

Hip flexion ROM in the dominant leg (defined as the preferred kicking leg because no significant difference between the two legs was found in the initial measurements) was measured using the Myrin goniometer (Lic. Rehab, Sweden). ROM assessments were first performed during a familiarization session, and the initial measurements showed strong agreement with those obtained during the experimental procedures. Measurements were performed independently by two trained examiners. Inter-rater reliability was assessed by calculating the intraclass correlation coefficient (ICC), which yielded a value greater than 0.95.

Countermovement Jump (CMJ)

Players performed maximal jumps with their hands on their waist using a countermovement with knee flexion at approximately 90°. Jump height was recorded using Opto-jump photocells (Microgate, Italy). Two trials were performed with a 30-srecovery between them, and the highest jump height was used for analysis.

Repeated Sprint Ability (RSA)

RSA was assessed using a 5 × 30 m test with 25-s intervals. This test was selected over similar tests because it exhibits a comparable decline in performance to those involving more repetitions (Chaouachi et al., 2010). Players began 40 cm before the first photocell and sprinted at maximal speed, crossing a second photocell line at 30 m. Recovery was active, with participants jogging lightly. Verbal cues indicating readiness were provided 10 and 5 s before each new sprint repetition. Statistical analysis included Total Time (TT), Fatigue Index (FI), and percentage decrement (%Decr).

Linear sprint 10 m and 30 m

Each player started 40 cm before the first photocell and sprinted at full speed to the final cone, placed 5 m after the third photocell, ensuring no reduction in speed before reaching the 30 m line. Two trials were performed, with 1 min of recovery between them, and the fastest time was selected for analysis.

Change of Direction (COD) [Arrowhead Agility Test (AAT)]

COD was measured using the AAT, which has been shown to reliably assess COD in soccer (Rago et al., 2020). The course was approximately 37 m, divided into shorter sections (Figure 2). Each player completed the test in both directions (right –AATR and left –AATL). Photocells were positioned 80 cm above the ground, and the best time from two attempts per direction (separated by 3 min) was used for analysis.

Measurements for the RSA, linear sprint, and COD tests were performed using the Newtest Powertimer 300 photocells (PC Upgrade Kit, FIN-90220, Oulu, Finland).

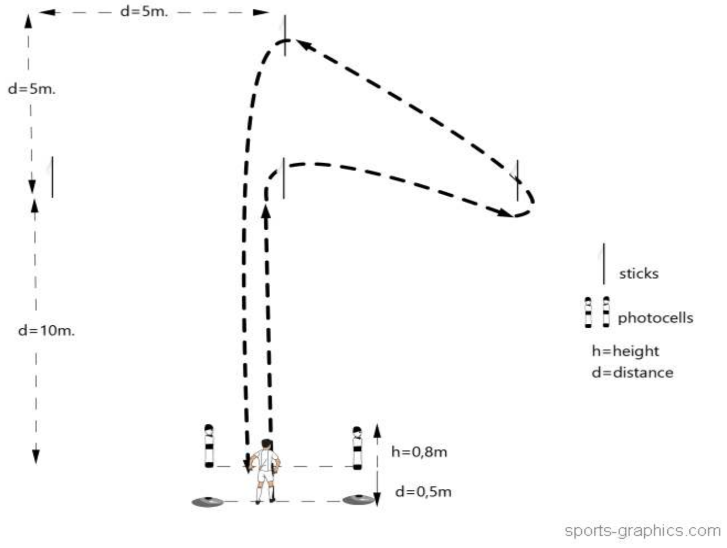


Figure 2. The Arrowhead Agility Test (AAT) and its execution procedure (shown to the right)

Statistical analysis

A two-factor mixed analysis of variance for repeated measures (program × time) was applied. A Shapiro–Wilk test was performed to assess the normality of the data across all variables, and standard parametric tests were used. Interaction effects were tested first, and if non-significant, main effects were evaluated. Greenhouse–Geisser corrections were applied when sphericity was violated. The Holm multiple comparisons test was used to identify individual differences among factor levels. Effect sizes were calculated using partial eta squared (η_p^2), with interpretations as follows: $\eta_p^2 < 0.01$ as negligible, $\eta_p^2 = 0.01–0.06$ as low, $\eta_p^2 = 0.06–0.14$ as moderate, and $\eta_p^2 > 0.14$ as high (Cohen, 1988). The threshold for statistical significance was set at $p < 0.05$.Statistical analyses were performed using the Jamovi software package (Version 1.2.17) (The Jamovi Project, 2023; R Core Team, 2022).

Results

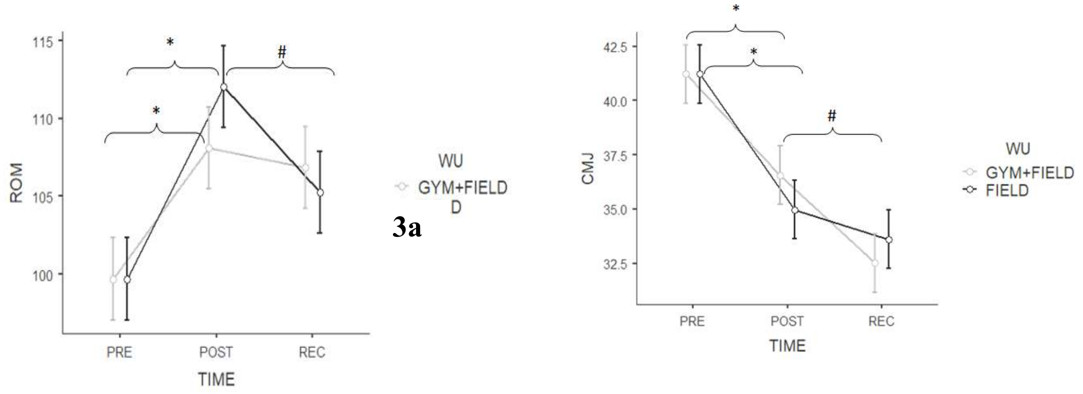
The two-factor analysis of variance revealed significant interactions for ROM ($F_{(2,30)} = 4.62$, $p < 0.001$, $\eta^2 = 0.236$) and CMJ ($F_{(2,30)} = 4.28$, $p < 0.02$, $\eta^2 = 0.222$). Additionally, a significant decrease in ROM and AATL performance was observed 15 min post-FIELD WU. In contrast, a significant decrease in CMJ jump height was observed 15 min post-GYM+FIELD WU. A trend toward decreased performance was also noted between the post-warm-up (POST) and recovery (REC) measurements for the 30 m sprint following FIELD WU ($p = 0.056$) and for AATR following GYM+FIELD WU ($p = 0.056$). No other significant changes were observed across the variables (Figures 3–5).

Range of Motion (ROM)

The ROM analysis revealed a significant interaction between factors ($F_{(2,30)} = 4.62$, $p<0.001$, $\eta^2 = 0.236$). Multiple comparisons using the Holm method showed no significant difference between POST and REC for GYM+FIELD WU ($p = 1$), despite a significant improvement in ROM from PRE to POST ($p < 0.002$). For FIELD WU, a significant improvement in ROM was observed between PRE and POST ($p < 0.001$), followed by a significant decrease from POST to REC ($p = 0.01$) (Figure 3a).

Countermovement Jump (CMJ)

Statistical analysis of CMJ performance showed a significant interaction ($\mathbf{F_{(2,30)}} = 4.28$, $p < 0.02$, $\eta^2 = 0.222$). No significant effect was observed for the "program" ($F_{(1,15)} = 0.17$, $p = 0.681$), but a significant main effect for "time" was identified ($\mathbf{F_{(2,30)}} = 56.63$, $p < 0.001$). Notably, the actual mean difference between the "programs" was moderate ($\eta^2 = 0.012$), while the effect for "time" was large ($\eta^2 = 0.791$).Further analysis revealed a significant decrease in performance from PRE to POST for both protocols ($p < 0.001$), with an additional decrease in performance from POST to REC for GYM+FIELD WU ($p < 0.001$)but not for FIELD WU ($p = 0.314$) (Figure 3b).



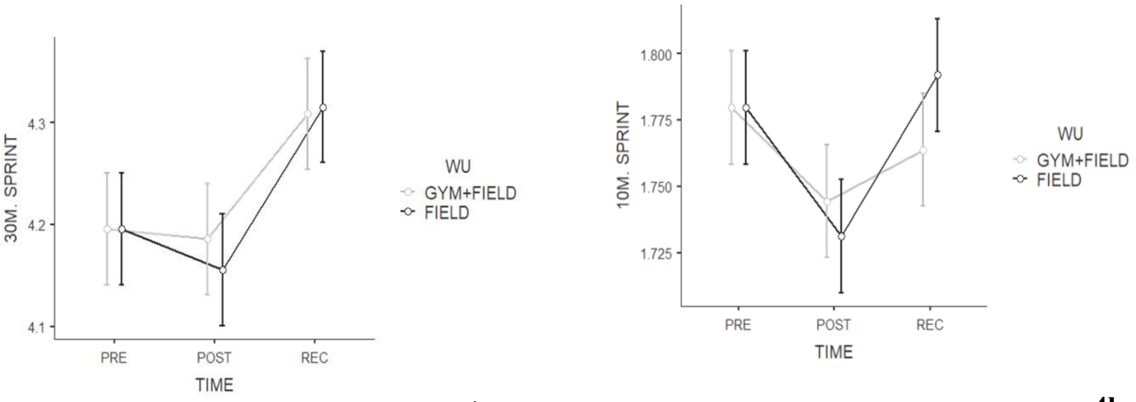
3a

3b

Figure 3. Changes in hip joint range of motion (ROM) (a) and CMJ (b) performance across three measurement time points for the two protocols. *Significant difference between the initial and post-protocol (PRE-POST) measurements. #Significant difference between post-protocol and 15-min recovery measurements (POST-REC) ($p<0.05$). GYM+FIELD WU: Warm-up protocol performed in the gym and on the field; FIELD WU: Warm-up protocol performed on the field; PRE: Measurement before protocol application; POST: Measurement after protocol application; REC: Measurement after a 15-min recovery period

Sprint Speed for 10m and 30m

For the 10 m sprint speed, no significant interaction was observed between factors ($\mathbf{F_{(2,30)}} = 1.366$, $p = 0.271$, $\eta^2 = 0.083$), nor were there significant main effects for "program" ($F_{(1,15)} = 0.224$, $p = 0.643$, $\eta^2 = 0.015$) or "time" ($\mathbf{F_{(2,30)}} = 2.376$, $p = 0.110$). However, although no significant differences were found for "time," the actual mean difference between time points was moderate ($\eta^2 = 0.137$). Similarly, the 30 m sprint speed showed no significant interaction ($\mathbf{F_{(2,30)}} = 0.189$, $p = 0.828$, $\eta^2 = 0.012$) and no main effect for "program" ($F_{(1,15)} = 0.089$, $p = 0.769$, $\eta^2 = 0.006$). However, a main effect for "time" was observed ($\mathbf{F_{(2,30)}} = 6.401$, $p < 0.005$), with a high difference between time points ($\eta^2 = 0.299$). Holm's analysis revealed a performance reduction trend from POST to REC after FIELD WU ($p = 0.056$) (Figures 4a, b).



4a

4b

Figure 4. Changes in performance for the 30 m (a) and 10 m (b) sprints across three measurement time points in the two protocols. *Significant difference between the initial and post-protocol (PRE-POST) measurements. #Significant difference between the post-protocol and 15-min recovery measurements (POST-REC) ($p<0.05$). GYM+FIELD WU: Warm-up protocol performed in the gym and on the field; FIELD WU: Warm-up protocol performed on the field; PRE: Measurement before protocol implementation; POST: Measurement after protocol implementation; REC: Measurement after a 15-min recovery period

Change of direction (Arrowhead Agility Test, AATR and AATL)

Analysis of COD revealed no significant interaction between factors for either AATR ($\mathbf{F_{(2,30)}} = 1.068$, $p = 0.357$, $\eta^2 = 0.066$) or AATL ($\mathbf{F_{(2,30)}} = 0.289$, $p = 0.75$, $\eta^2 = 0.019$). No significant main effect of "program" was observed for either direction (AATR: $F_{(1,15)} = 0.158$, $p = 0.696$, $\eta^2 = 0.010$; AATL: $F_{(1,15)} = 0.08$, $p = 0.781$, $\eta^2 = 0.005$). However, a significant main effect of "time" was found for both AATR ($\mathbf{F_{(2,30)}} = 5.661$, $p < 0.008$, $\eta^2 = 0.274$) and AATL ($F_{(1.36,20.43)} = 6.724$, $p < 0.011$, $\eta^2 = 0.31$), Holm's test showed a performance decline from POST to REC for GYM+FIELD WU in AATR ($p = 0.05$) and for FIELD WU in AATL ($p = 0.03$) (Figures 5a, b). In terms of the "time" variable, substantial mean differences were noted for both AATR and AATL.

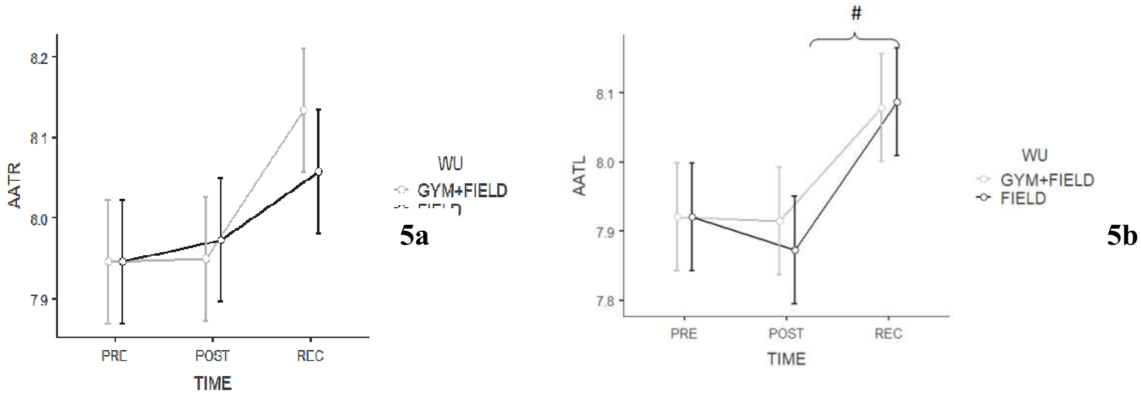


Figure 5. Changes in performance for AATR (a) and AATL (b) across three measurement times in the two protocols. *Significant difference between the initial and post-protocol (PRE-POST) measurements. #Significant difference between the post-protocol and 15-min recovery measurements (POST-REC) ($p<0.05$). GYM+FIELD WU: Warm-up protocol performed in both the gym and on the field; FIELD WU: Warm-up protocol performed on the field; PRE: Measurement before protocol implementation; POST: Measurement after protocol implementation; REC: Measurement after a 15-min recovery period

Body Temperature (T_e) and Heart Rate (HR)

No significant interaction between factors was observed for either body temperature ($\mathbf{F}_{(2,30)} = 0.416$, $p = 0.663$, $\eta^2 = 0.004$) or heart rate ($\mathbf{F}_{(2,30)} = 3.053$, $p = 0.07$, $\eta^2 = 0.002$). Likewise, no main effect of "program" was found for either variable (Te: $F_{(1,15)} = 3.334$, $p = 0.986$, $\eta^2 = 0.000$; HR: $F_{(1,15)} = 0.002$, $p = 0.961$, $\eta^2 = 0.000$), with the actual mean differences for the "program" factor in both Te and HR being negligible ($\eta^2 < 0.001$). However, a significant effect of "time" was observed for both body temperature ($\mathbf{F}_{(2,30)} = 14.301$, $p < 0.001$) and heart rate ($\mathbf{F}_{(2,30)} = 541.411$, $p < 0.001$). Significant increases were observed between PRE and POST for both protocols, with significant decreases from POST to REC ($p < 0.05$ for all) (Figures 6a, b). However, for the variable Te, the actual mean difference was high ($\eta^2 = 0.162$), while for the variable HR, the mean difference was negligible ($\eta^2 < 0.001$).

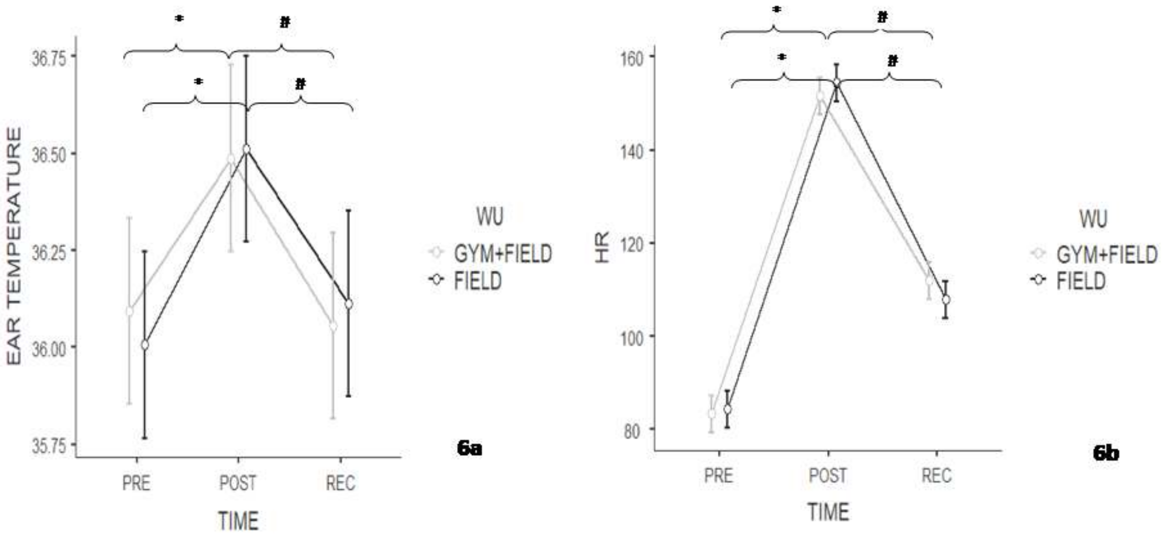


Figure 6. Changes in body temperature (T_e) (a) and heart rate (HR) (b) across three measurement times for the two protocols. *Significant difference between the initial and post-protocol (PRE-POST) measurements. #Significant difference between post-protocol and 15-min recovery measurements (POST-REC) ($p<0.05$). GYM+FIELD WU: Warm-up protocol performed in the gym and on the field; FIELD WU: Warm-up protocol performed on the field; PRE: Measurement before protocol implementation; POST: Measurement after protocol implementation; REC: Measurement after a 15-min recovery period; HR: Heart rate

Discussion

The primary objective of this study was to evaluate the impact of the 15-mintransition period between the completion of the warm-up and the start of the match, as mandated by professional soccer competition rules, on players' performance. Two warm-up protocols were used in this study: (1) the traditional field warm-up (FIELD WU), which lasted approximately 25 min, and (2) a combined warm-up that included pre-activation exercises in the gym followed by the traditional field warm-up (GYM+FIELD WU), totaling 47 min in duration. Pre-activation exercises in the gym before field activities are commonly used by high-level soccer teams to enhance player performance. However, to our knowledge, this practice has not been adequately explored in the scientific literature.

The two-factor analysis of variance revealed significant interactions only for ROM and CMJ. This study also demonstrated that a 15-min passive recovery period following warm-up resulted in declines in soccer players' performance metrics, including CMJ, ROM, and COD. Specifically, performance reductions were observed in CMJ and AATR 15 min after the GYM+FIELD WU protocol and in hip flexion ROM, AATL, and 30 m sprint speed following the FIELD WU protocol. These findings suggest that both warm-up protocols lose efficacy over the 15-min transition period owing to physiological and muscular cooling effects, potentially impairing performance at the start of the match.

As reported, the performance benefits of warm-up are closely related to elevated body and muscle temperature (Bishop, 2003a), which enhance neuromuscular responsiveness and facilitate faster muscle contractions (Kilduff et al., 2013a; Mohr et al., 2004). In contrast, a period of inactivity can result in an increase in the stability of actin–myosin bonds and increased muscle stiffness, slowing cross-bridge cycling and leading to a reduced rate of force development (RFD) (Berg & Ekblom, 1979; Bishop, 2003a; Racinais & Oksa, 2010; Silva et al., 2022).In this study, ear canal temperature measurements showed a significant body temperature decrease (0.3°C) after 15 min of inactivity. This temperature reduction likely contributed to increased muscle stiffness, decreased cross-bridge cycling, and a subsequent reduction in the RFD, impairing explosive power output and ROM (Bishop, 2003a; Galazoulas et al., 2012; Kilduff et al., 2013a). Additionally, the significant difference observed between the POST and REC measurements in the FIELD WU protocol can likely be attributed to the fact that hip flexion ROM at the POST measurement was greater (though not significantly) in the FIELD WU protocol compared to GYM+FIELD WU. Consequently, the decrease in temperature had a more pronounced effect on ROM following the FIELD WU protocol.

Consistent with prior findings, Kilduff et al. (2013b) observed a strong correlation (r = 0.71) between post-warm-up body temperature declines and reduced lower limb power. Similarly, studies by Crowther et al. (2017) and Galazoulas et al. (2012) reported decreases in jump height of 12%–20% following a 20–40 min inactive period, which were attributed to body temperature reductions of approximately 0.5°C–0.7°C. Despite this, existing literature suggests that short-duration efforts may benefit from a brief recovery period of 5–20 min (Dawson et al.,1997).The intensity and duration of the warm-up should not exceed 60% of VO_{2max} and should last 10–20 min (Bishop, 2003a,b). However, in this study, the warm-up protocol applied (GYM+FIELD WU) was relatively long (47 min), and its intensity, particularly during the field portion, was approximately80% of HR_{max} or approximately 70% of VO_{2max}. This likely led to fatigue, meaning that the 15-minrecovery period was insufficient for full recovery.

Temperature-independent mechanisms, such as oxygen consumption (VO_2), PAP, and PAPE (Bishop, 2003a; Blazevich & Babault, 2019),may also influence post-warm-up performance changes. Elevated VO_2 after warm-up helps reduce anaerobic contributions to initial efforts (Bishop, 2003a). However, VO_2 levels typically return to baseline in approximately 5 min post-exercise, suggesting that a 15-min recovery period may be insufficient to sustain enhanced aerobic readiness (Powers & Howley, 2018). This is supported by research from Lovell et al. (2007), where professional soccer players who underwent a re-warm-up following the Bangsbo soccer test demonstrated a higher baseline VO_2, likely contributing to improved performance in specific endurance.

Elevated post-exercise oxygen consumption (EPOC) may have further affected performance by increasing the initial oxygen deficit during subsequent anaerobic efforts (Powers & Howley, 2018). Research indicates that high-intensity exercise can prolong EPOC, delaying VO_2 recovery for up to 14 min post-exercise (Powers & Howley, 2018). As a result, players may experience reduced aerobic efficiency when initiating a new action or starting a match after a 15-min recovery, potentially hindering performance in explosive movements or repeated sprints.

PAP refers to a brief increase in muscle performance, lasting from seconds to min, following intense muscle activation, primarily owing to myosin light chain phosphorylation in type II fibers (Xenofondos et al., 2010; Blazevich & Babault, 2019). Active warm-ups are known to trigger PAP (Bishop, 2003a; Golas et al., 2016;Tillin & Cooke, 2009). In contrast, PAPE involves more prolonged improvements in muscle force production, driven by factors such as increased muscle temperature, intracellular water retention, and heightened muscle activation, with effects lasting several minutes (Blazevich & Babault, 2019). PAP and PAPE are both influenced by fatigue, which can reduce their effectiveness, particularly when exercise volume and intensity are high (Tsoukos et al., 2013). In this study, as previously mentioned, the high-intensity and prolonged warm-up, followed by a 15-min recovery, may have led to reduced jump performance, likely owing to a decrease in muscle temperature, which could negatively impact PAPE (Blazevich & Babault, 2019). Notably, Petisco et al. (2019) observed improvements in jump performance after a 15-min recovery following warm-ups with and without PAP exercises in professional soccer players. However, owing to the lack of baseline measurements, direct comparisons with this study are challenging. The conflicting results are likely attributed to the intensity and content of the warm-up, the assessment test, the participants' level, and their individual characteristics (Sole et al., 2013).

A decreasing trend was observed only in AATR performance following the 15-min recovery after the GYM+FIELD WU program. In a related study, Petisco et al. (2019) found reduced COD performance on the T-test 15 min after a FIELD-like WU program in professional soccer players, with improved results when the warm-up included half-squats at 80% 1RM (7.23 vs. 7.12 s). Similarly, Sole et al. (2013) observed no improvement in COD performance following three half-squat reps at 90% 1RM after a 12-min inactivity period in collegiate athletes. Improvements in COD may result from the development of reactive force, which promotes acceleration by facilitating rapid concentric–eccentric transitions (Petisco et al., 2019). In contrast, this study did not employ equivalent loading, using only elastic resistance bands and core exercises, which may explain the lack of significant COD improvement. Notably, the gym-based portion of the GYM+FIELD WU protocol initially increased right leg concentric strength in both the flexor and extensor muscles (predominantly in the right leg for most participants) at 180°/s (Kyranoudis et al., 2021). However, this force enhancement likely decreased15 min post-WU owing to a decrease in body temperature, which is known to affect peak lower-limb power (Growther et al., 2017).

In comparison, a decrease in leftward change-of-direction (AATL) performance was only noted following the FIELD WU protocol. Although the final performance values after 15 min of recovery (REC) showed no significant difference between the two protocols (8.08 vs. 8.09 s), a minor, non-significant difference was observed immediately after the warm-up (POST) (7.91 vs. 7.87 s). This pattern may have affected the final REC measurement because performance fluctuations were similar in both protocols. The enhanced POST performance in the FIELD WU group might be linked to reduced fatigue owing to a shorter warm-up duration compared to the combined GYM+FIELD WU, which could help explain the similar decline in COD performance observed across conditions after 15 min of recovery.

In terms of speed (including acceleration and maximum speed) and RSA, assessed through TT, FI, and % Decr indices (Glaister et al., 2008), this study found no interactions between factors and significant differences 15 min post-warm-up, despite an observed decline in performance. These results contradict findings from other studies (Growther et al., 2017; Mohr et al., 2004; Petisco et al., 2019). The observed reductions in speed, COD speed, and jumping ability following a short recovery period are likely attributed to decreases in body and muscle temperature, as well as heart rate (Growther et al., 2017; Silva et al., 2018). Galazoulas et al. (2012) observed a 4%–6% decrease in speed, with a greater decline in acceleration (10 m), in basketball athletes within 10 min post-warm-up as body temperature decreased. Similarly, Mohr et al. (2004) reported a 2°C temperature decrease during a 15-min halftime in soccer, which correlated with decreases in speed performance ($r = 0.60$). Furthermore, Silva et al. (2022) reported a gradual decline in jump and RSA performance as the recovery duration increased.

The absence of significant differences between POST and REC measurements in this study likely reflects the timing of the POST measurement, taken approximately 5 min after the warm-up. As previously mentioned, the timing of measurements plays a critical role in influencing performance outcomes following PAP or PAPE protocols (Blazevich & Babault, 2019; Chatzopoulos et al., 2007; Guinubi et al., 2015). At this early POST interval, fatigue may have overshadowed the effects of PAP, resulting in less representative results. PAP typically manifests during initial muscle contractions and decreases with continued activity, favoring single, explosive movements such as jumping rather than repetitive actions such as sprinting, which depend on sustained contractions (Needman, Morse & Degens, 2009).Additionally, players were measured in groups of four, which made simultaneous measurements—particularly in RSA—challenging. This arrangement may have introduced variability because some players were nearing fatigue while others still demonstrated PAP effects, potentially balancing the results. Consequently, the REC measurement may not indicate a significant decline, even though there was a decrease in body temperature and possible PAPE effects. Body temperature seems to enhance individual sprint performance but has a lesser impact on repeated sprints (Linnane et al., 2004; Racinais & Oksa, 2010). This could help explain the lack of significant differences in RSA, although findings on this remain inconsistent (Mohr et al., 2004).

The specific warm-up protocol used in this study suggests that the timing of POST measurements likely affected the results. Petisco et al. (2019) discovered that professional soccer players recorded better 30 m sprint times 15 min after performing 10 half-squat repetitions at 60% of their 1RM, in comparison to a traditional soccer warm-up. Similarly, Guinubi et al.(2015) reported improved mean sprint times in RSA (7 × 30 m, with 25-s rest intervals) when a 5-min sprint exercise was included at the end of the warm-up rather than before a specialized warm-up period.

Mohr et al. (2004) indicate that VO_2 kinetics are crucial for repetitive sprint performance at the beginning of the second half of a soccer match, especially after a 15-min passive recovery. VO_2 levels can be maintained more effectively when the interval between efforts does not exceed 5 min (Bishop, 2003a; Bangsbo et al., 2001). However, a 15-min break may be excessively long for players to quickly engage in anaerobic activities that rely on aerobic recovery. Heightened EPOC resulting from an intense warm-up may prevent VO_2 from returning fully to baseline, thereby restricting aerobic support during high-intensity sprints. Additionally, if players did not perform sprints with maximal effort (van den Tillaar & von Heimburg, 2019), this could further explain the lack of significant differences in the final measurement.

In addition to the physiological and neurological factors that may have impacted player performance in this study, the duration and intensity of the warm-up warrant serious consideration. Yanci et al. (2019) found that longer warm-up protocols resulted in increased fatigue, which corresponded to higher Rate of Perceived Exertion (RPE) values. Silva et al. (2018) agree with this perspective, stating that intense and prolonged warm-up sessions lead to accumulated fatigue that adversely affects subsequent performance in short-term all-out efforts. Similarly, van den Tillaar et al. (2016) reported high RPE values after prolonged warm-ups; however, they attribute the performance decline more to the specific content of the warm-up rather than its duration. This viewpoint is further supported by Taylor et al. (2013). As previously noted, the warm-up durations in this study were 25 and 47 min for each protocol, respectively, with an intensity of approximately 70% of VO_{2max}. These factors may have adversely affected the players' performance, contributing to accumulated fatigue.

While this study offers valuable insights into the short-term benefits of warm-up protocols, certain limitations must be acknowledged. First, the sample consisted of players from a semi-professional team who were available only after the season ended, limiting the generalizability of the findings. Although the implementation of pre-warm-up actions has become standard practice, the prolonged duration of the warm-up may have influenced the results. The number of tests likely influenced the results because there was a 7–10 min time period in the test groups that should be added to the duration of the warm-up, followed by the 15-min recovery period. A similar program with fewer tests might have yielded different results. Finally, while measuring temperature from the ear canal is an acceptable method, it may have produced different results compared to more direct measurement procedures.

Conclusion

Given the conditions of professional and semi-professional soccer competitions, where there is a 15-min period of inactivity between the end of the warm-up and the start of the game, this study examined the effects of a combined warm-up program that included gym exercises and specialized on-field warm-up (GYM+FIELD WU) versus the traditional on-field warm-up only (FIELD WU). The aim was to evaluate their impact on variables that determined player performance. The findings indicate that this 15-min interval may result in decreased ROM, lower limb power, and COD speed after both warm-up protocols. This may hinder players' ability to fully benefit from their warm-up, potentially impacting their readiness at the start of the match. In light of these observations, it is recommended that coaches and fitness trainers implement a re-warm-up protocol shortly before kickoff to help address potential performance declines. Additionally, further research is necessary to confirm these trends and to investigate the optimal timing and methods for re-warm-up activities.

Conflicts of interest No potential conflict of interest were reported by the author.

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