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ORIGINAL RESEARCH

Cognitive effect of 7-min re-warm-up after half-time in under-16 soccer players

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Abstract

Background: A review of the literature indicates that the physical performance of soccer players declines during the early minutes of the second half. However, incorporating re-warm-up (RWU) strategies has proven to significantly boost their performance during this critical period. **Objective:** The present study aimed to examine the acute effects of a re-warm-up on cognition, as reflected in the Psychomotor Vigilance Task (PVT). **Methods:** Twenty-two male under-16 soccer players from a non-professional team in Andalusia, Spain, successfully completed the study. These players were divided into two parallel groups: a control group and an experimental group. The young soccer players were evaluated using the Yo-Yo Intermittent Recovery Test to obtain VO_2max. Additionally, heart rate was monitored with a heart rate monitor, and PVT was assessed using a mobile application. **Results:** A *t*-test was used to analyze heart rate and PVT data over a 5-min period. The results showed that soccer players responded faster after performing a RWU (315.82 ± 32.31 ms) than the control group after traditional rest (350.59 ± 50.23 ms), p = .001, d = –0.58. **Conclusions:** The results of this study suggest that a 7-min RWU after half-time improves reaction time. The findings offer valuable insights that soccer coaching staff can utilize to enhance their team's performance.

Keywords: cognition, exercise, soccer, re-warm-up, vigilance

Introduction

A review of the literature reveals several studies investigating the impact of acute fatigue on cognitive performance in team sports players (Skala & Zemková, 2022). Most of this research has concentrated on how acute fatigue affects cognitive control (Dambroz et al., 2022; González-Víllora et al., 2022) and cognitive abilities such as working memory and short-term memory, which are key distinguishing characteristics among athletes (Verburgh et al., 2016). Additionally, factors like processing speed and decision-making, measured through reaction times and accuracy, are critical in team sports (Bashore et al., 2018; Hodges et al., 2006; Voss et al., 2010). Therefore, the present study evaluated the effects of rest at half-time to elucidate the acute effects of a re-warm-up (RWU), which is known to positively impact physical variables such as vertical jump height and sprint performance (Silva et al., 2018). To our knowledge, no prior research has focused on concurrent cognitive performance during this period. Given that performance varies throughout a game, it is essential to continuously monitor cognitive functions.

Regarding the RWU in soccer, it should be noted that it can be performed before the start of the second half of a match. In this sense, in a systematic review, Russell et al. (2015) explored the effects of RWU on soccer players, revealing its efficacy at the physical level. The literature also highlights a decrease in physical performance among soccer players during the second half of competitive match-play (Mohr et al., 2005; Weston et al., 2011), primarily attributed to fatigue (Bradley et al., 2009) and a reduction in body temperature due to passive half-time practices (Mohr et al., 2004). RWU strategies have shown improvements in soccer players' acute performance during the second half of a match (Edholm et al., 2014; González-Fernández et al., 2023; Hammami et al., 2018). However, there are no previous studies linking RWU with cognitive performance improvement.

Currently, there are very few studies that examine the cognitive effects on soccer players after or during the exercise. For example, González-Fernández, Sarmento, et al. (2022) performed a counterbalanced cross-over study with youth soccer players, demonstrating the positive effects of warm-up (WU) on vertical jump height, linear sprinting, and reaction times (RTs) in a Psychomotor Vigilance Task (PVT; Wilkinson & Houghton, 1982). The PVT presents a valuable opportunity to measure vigilance, a high-order

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cognitive function crucial for maintaining attention over extended periods and responding appropriately to infrequent stimuli (Sarter et al., 2001). An appropriate level of vigilance is critical during sports, work environments, and conditions of sleep deprivation, among other scenarios. These changes are generally attributed to fatigue, task duration, or the intensity of the work performed. Previous research has shown that the PVT is very sensitive to decreases in vigilance (Helton & Warm, 2008), typically manifested as increased RTs.

In the present research, we set the duration of the PVT to 5 min to observe vigilance after a re-warm-up (RWU), enabling the deployment of adequate attention, which significantly influences cognitive control (Langner & Eickhoff, 2013). Based on previous research conducted after a warm-up (WU; González-Fernández, Sarmento, et al., 2022), we hypothesized that an RWU would improve vigilance. Specifically, we expected that these improvements would result in faster RTs in the experimental group (EG) after an RWU compared to the control group (CG). This hypothesis aligns with the inverted U-shape arousal hypothesis (Yerkes & Dodson, 1908) and the physiological changes induced by exercise (Davranche & Audiffren, 2004; Leitzelar et al., 2020; McMorris & Hale, 2015). Thus, the purpose of the present study was to examine the acute effects of an RWU on the PVT in twenty-two under-16-year-old soccer players (CG vs. EG).

Methods

Participants

A total of twenty-two under-16-year-old male soccer players from one nonprofessional team of the Andalusian autonomic division, Spain (11 in the CG and 11 in the EG) successfully completed the study (see Table 1). The study was conducted in season when soccer players attended football training sessions twice per week and played competitive matches at least once a week.

The participants' parents or guardians were informed of the protocol, main aims, and experimental risks of the investigation, and signed an informed consent form before the subjects participated in the investigation. The study was conducted in adherence to the standards of the Helsinki Declaration and approved by the Institutional Ethical Committee (Resolution 2021/89). The inclusion criteria for the present research were (a) reported normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (b) being an active player of the federated team, (c) not presenting any injuries during the study, and (d) legal guardians giving informed consent.

Material and testing

Anthropometrical assessment

Height (cm) was measured using a stadiometer (SECA 225, SECA Seca Corp, Hamburg, Germany) to the nearest 0.1 cm, and body mass (kg) was measured without shoes with a bioelectrical impedance analysis device (Tanita BC-730, Tanita, Tokyo, Japan) to the nearest 0.1 kg. Both measures were taken at the beginning of the study. In addition, body mass index (BMI) was calculated.

Yo-Yo Intermittent Recovery Test – Level 1

The Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT Level 1), was carried out in accordance with the suggested protocol given by González-Fernández et al. (2020). In the end, the completed number of the level and the total distance travelled in meters at the end of the test were recorded. Maximal oxygen uptake (VO_2max in milliliters per minute and kilogram) was estimated using the following equation: VO_2max = final distance (in meters) * 0.0084 + 36.4.

Heart rate

A M400 Polar monitor (Polar Electro, Helsinki, Finland) was used to monitor and record heart rate (HR) during the experimental session in all the participants of both groups.

PVT

The task included a single block lasting 5 min. The PVT was carried out in accordance with the suggested

Table 1 Participants characteristics

Variable	Control group (*n* = 11)				Experimental group (*n* = 11)			
	Mean ± *SD*	Minimum	Maximum	Range	Mean ± *SD*	Minimum	Maximum	Range
Anthropometrical measures								
Age (years)	15.38 ± 0.51	14.09	15.99	1.90	15.32 ± 0.57	14.42	15.99	1.57
Body mass (kg)	62.47 ± 13.59	42.70	84.50	41.80	67.61 ± 8.58	52.30	81.30	29.00
Height (cm)	171.18 ± 7.60	158.00	181.00	23.00	172.27 ± 5.53	165.00	181.00	16.00
Body mass index (kg/m^2)	21.45 ± 5.02	13.03	29.24	16.21	23.46 ± 2.34	17.91	27.51	9.60
Physical fitness								
VO_2max (mL/min/kg)	43.43 ± 5.49	36.40	51.18	14.78	40.13 ± 3.98	36.40	49.84	13.44
Heart rate (beats per minute)								
First half	174.05 ± 9.55	158.60	188.97	30.37	173.26 ± 6.17	166.34	182.23	15.89
Resting	106.30 ± 7.18	95.20	115.23	20.03	108.43 ± 5.90	100.90	117.29	16.39
Second half	125.94 ± 10.92	99.18	139.18	40.00	178.53 ± 6.30	167.31	187.71	20.40
Psychomotor Vigilance Task								
First half reaction time (ms)	307.17 ± 42.93	235.29	400.65	165.36	294.67 ± 35.95	248.47	380.92	132.45
Second half reaction time (ms)	315.82 ± 32.31	296.51	479.20	182.69	350.59 ± 50.23	277.56	369.03	91.47

Note. VO_2max = estimated maximal oxygen uptake.

protocol given by González-Fernández, Latorre-Román, et al. (2022). A total of 22 iPhone 5s (iOS v12.4.5; Apple, Cupertino, CA, USA) were used to present the stimuli of the PVT at the same time (concurrently). Crucially, soccer players were familiarized with the PVT; nonetheless, they were given verbal and written instructions prior to the start of the PVT at each moment (Figure 1). Additionally, the PVT utilized the app Vigilance Buddy (Version 1.55; https://researchbuddies.com).

Procedure

Researchers visited the field on two different days: (a) test session, and (b) match session (see Figure 2). They always visited at the same time of day (5:30–6:30 p.m.), and both visits were performed on the same day of the week (Tuesday) but in two different weeks. Environmental conditions (location, temperature, and humidity) were similar in both sessions.

Figure 1 Setting and instruction to understand the use of Psychomotor Vigilance task

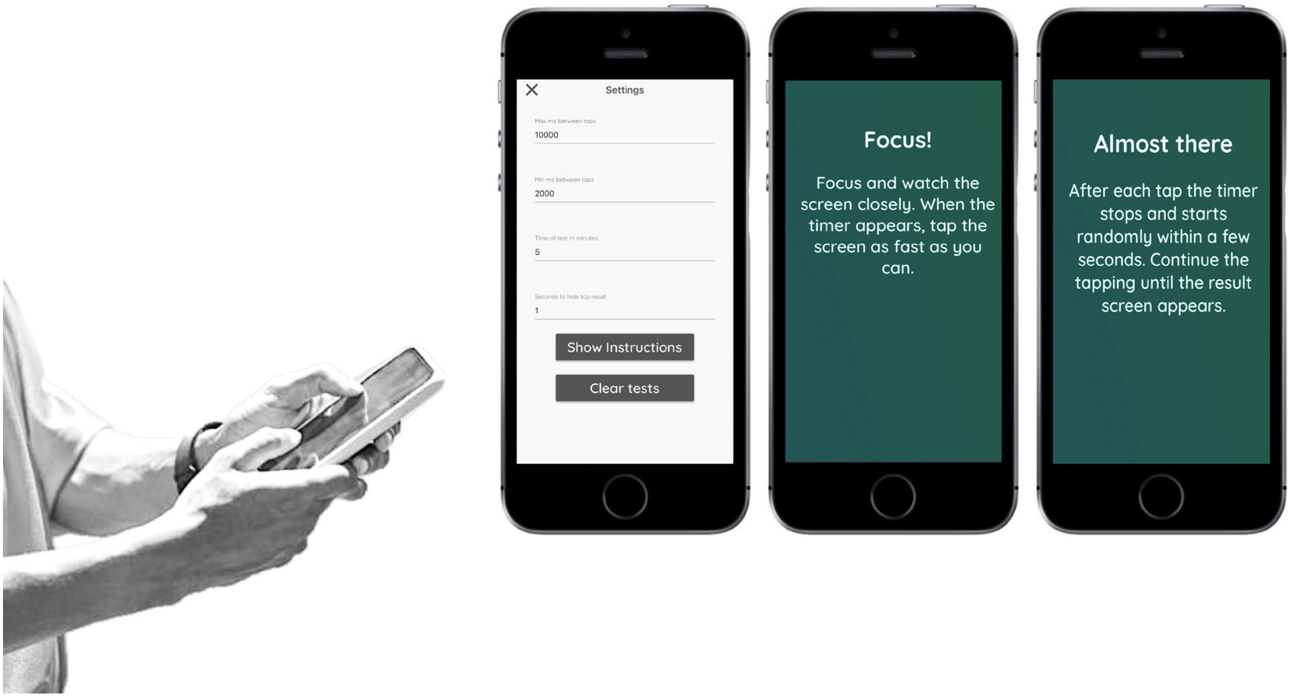
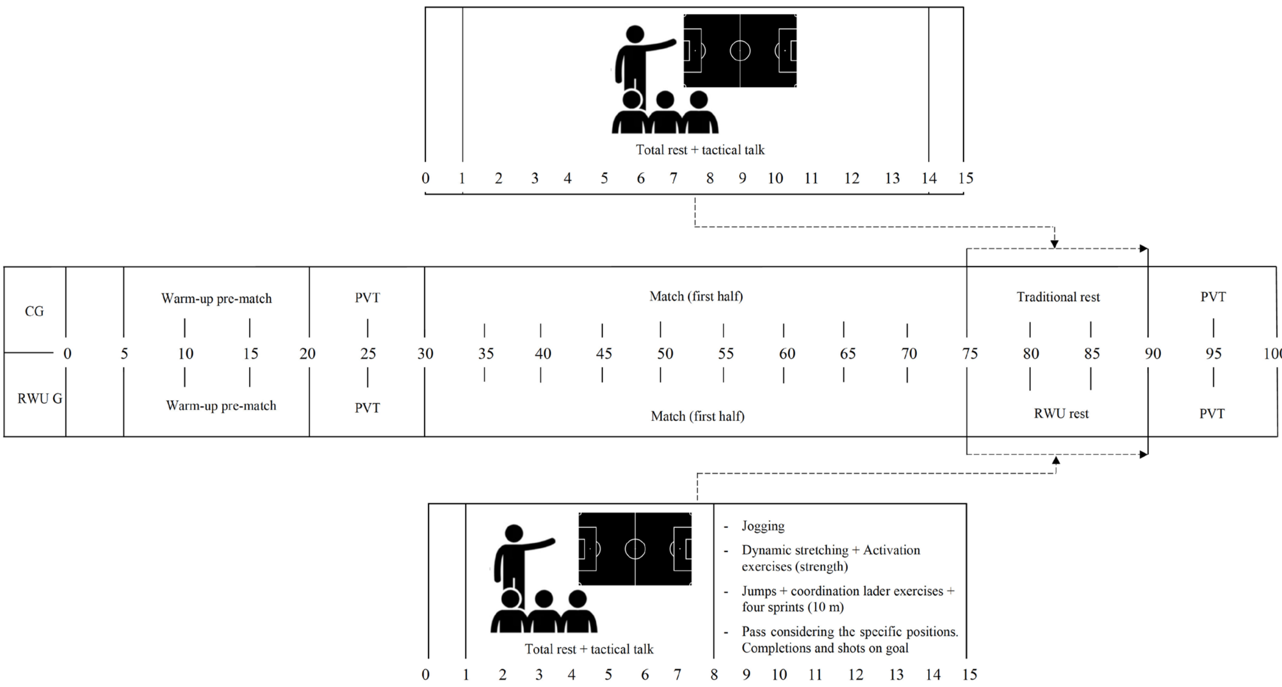


Figure 2 Schematic representation of match session



Test session

First, we ensured that the relative responsible for each participant signed the informed consent form, which detailed the possible benefits and risks of participation. To prevent players from missing training time, we collaborated with the technical staff to conduct rapid registrations beforehand. To ensure accurate and reliable data recording, during this testing session, the anthropometric measurements were recorded first. Afterwards, the players completed 5 min of the PVT to familiarize them with the task (Figure 3), and the EG was familiarized with the RWU protocols. In addition, the players performed the YYIRT Level 1.

Match session

In the second session, participants played an 11 vs. 11 match. When the young soccer players finished the first half, they returned to their dressing room in order to receive tactical instructions from the coach while they remained seated in silence. One group (CG) performed a traditional rest of 15 min and subsequently went back to the field to perform the PVT. However, the other group (EG), after the tactical instructions of 8 min, returned to the field and performed an RWU of 7 min: jogging to the field (1 min), dynamic stretching and activation exercises (2 min), jumps, coordination ladder exercises and sprints of 10 m (2 min) and passes considering the specific position, and completions and shots on goal (2 min). Next, participants performed the PVT for 5 min. For more information, see Figure 2.

Statistical analysis

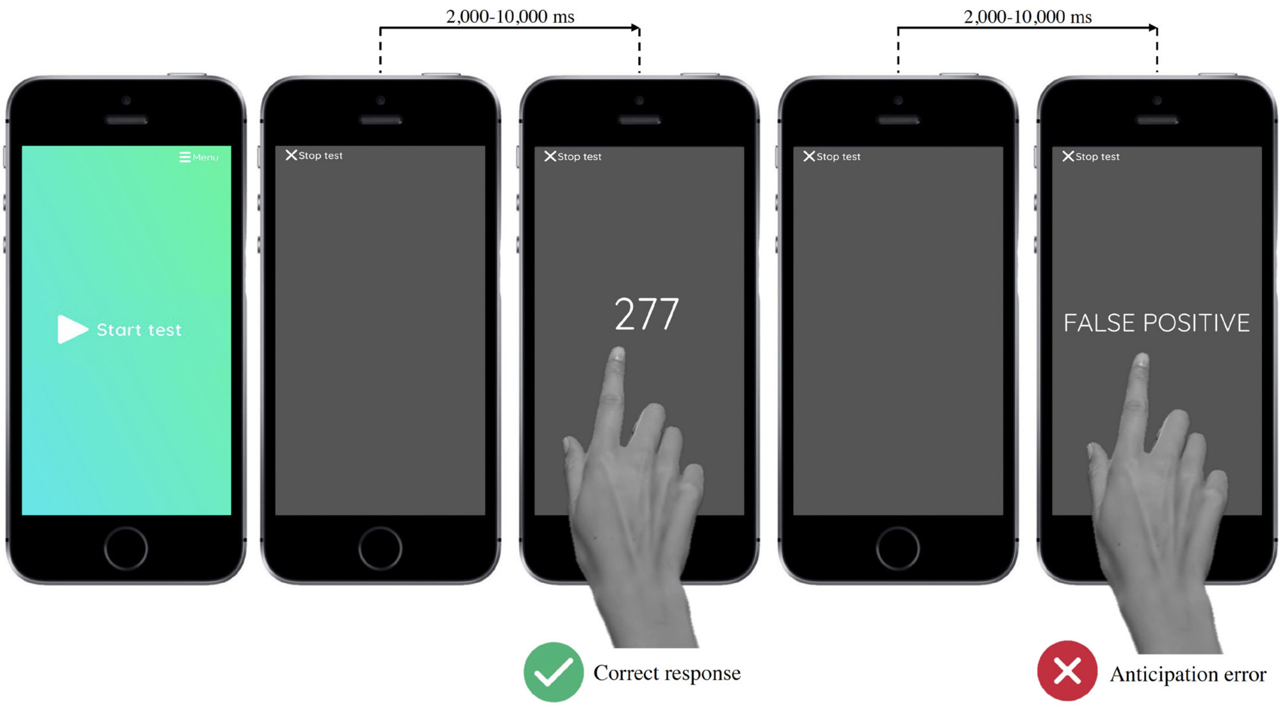
The current study employed a within-participants design that examined the factors of effort condition (CG vs. EG) and moment, specifically analyzing HR during the first half, rest period, and second half, as well as the PVT results for the first and second halves. To assess the HR and PVT outcomes measured over a 5-min interval, analyses of variance (ANOVAs) were conducted. Prior to performing the ANOVA, the normality of the data distribution was evaluated using the Shapiro-Wilk test, and the homogeneity of variance was assessed via Levene's test. Additionally, planned comparisons were conducted to clarify the differences between groups across various interactions. Effect sizes for *t*-tests were calculated using Cohen's *d* values, while partial eta-squared values were used for *F*-tests. Data analysis was carried out using IBM SPSS Statistics for Windows (Version 26.0; IBM, Armonk, NY, USA). A significance level of $p < .05$ was established for all analyses.

Results

HR

An ANOVA was conducted to compare the mean HR of the CG and the EG across different moments (first half, rest, and second half). The results indicated a significant main effect of condition, $F(1, 10) = 54.80$, $p = .001$, a significant main effect of moment, $F(2, 20) = 492.08$, $p = .001$, and a significant interaction between condition and moment, $F(2, 20) = 132.64$, $p = .001$. In the context of this interaction, planned comparisons were carried out for the HR recorded immediately after the completion of the first half. The comparison between the CG and EG did not yield significant differences, $p = .86$, $d = 0.10$. Similarly, HR measurements taken during the rest period did not show significant differences between groups, $p = .36$, $d = -0.32$. However, HR measurements recorded immediately following the RWU exhibited significant differences,

Figure 3 Example of one trial of the Psychomotor Vigilance task



with the EG demonstrating a higher HR compared to the CG, p = .001, d = 0.58.

PVT

An additional ANOVA was conducted to examine the mean PVT values obtained following the completion of the warm-up for the first half. The analysis revealed a significant main effect of condition, $F(1, 10) = 4.96$, $p = .05$, as well as a significant main effect of moment, $F(1, 10) = 9.12$, $p = .01$. However, the interaction between condition and moment did not yield a significant effect, $F(1, 10) = 3.82$, $p = .08$. Furthermore, planned comparisons related to the interaction did not indicate significant differences in PVT values following the completion of the first half warm-up, $p = 0.37$. Importantly, another similar analysis of PVT reaction times after the RWU demonstrated significant differences, $p = .03$, $d = –0.62$. Participants exhibited generally faster response times after completing the RWU compared to those following traditional rest.

Discussion

The aim of the present research was to examine the acute effects of an RWU on a PVT in twenty-two under-16-year-old soccer players. Overall, the results suggest that a structured RWU significantly enhanced the PVT performance, specifically on vigilance. In addition, these results were also reinforced by heart rate responses in both groups. Thus, we found similar results after the first half, similar heart rate decrement in both groups at half-time, and crucially, differences after the RWU, showing higher values in the EG than in the CG. These findings align with the existing literature which suggests that traditional passive rest during half-time can negatively impact the physical performance of professional soccer players in the early stages of the second half (Abade et al., 2017, Edholm et al., 2014, González-Fernández et al., 2023, Hammami et al., 2018, Lovell et al., 2013).

Such results emphasize the potential advantages of incorporating dynamic warm-up routines over traditional resting methods, particularly in optimizing performance and conditioning during competitive play. It is fully recognized that performing an RWU promotes higher overall performance in the physical parameters of soccer players due to maintaining muscle temperature and preserving neuromuscular factors that will be applicable to the match such as sprints, dynamic strength, and jump performance (Lovell et al., 2013). However, in line with our hypothesis, the benefits of performing a RWU and improving the RTs in the EG in comparison to the CG, suggest better vigilance after 7 min of RWU protocols. These results are consistent with the recent literature performed after a WU in young soccer players (González-Fernández et al., 2023), under-19 soccer players (González-Fernández, Latorre-Román, et al., 2022), or soccer referees (Busquets-Ferrer et al., 2022). For instance, efficient vigilance would reduce the probability of soccer player error and would obviously impact processing speed and decision-making (Bashore et al., 2018; Hodges et al., 2006; Voss et al., 2010), which are key factors in soccer performance.

As has been discussed, this finding suggests a facilitation effect on vigilance after an RWU and provides support to previous research that showed that a WU had selective effects over cognitive processing (González-Fernández, Sarmento, et al., 2022). Crucially, the inclusion of uncertainty regarding the appearance of the target in the PVT (2,000 to 10,000 ms) makes it different from simple RT tasks and provides a reliable instrument for measuring vigilance (Helton & Warm, 2008). In fact, different studies performed with the PVT are also supported by neuroimaging studies (Drummond et al., 2005) revealing brain activity linked to the vigilance network. For this reason, the physical exercise not only improved the non-specific response speed but also improved participants' vigilance. Regarding HR, it should be mentioned that both were clearly differentiated after half-time in the activity (RWU vs. traditional rest) and intensity (125.94 ± 10.92 bpm vs. 178.53 ± 6.30 bpm). Therefore, according to acute changes in arousal produced by the RWU and the physiological changes (increases in body temperature, neurotransmitters, cerebral blood, and cortical activation, among others; McMorris & Hale, 2015) the vigilance improvements could be affected by 7 min of RWU.

The present study presents some limitations. First, the study lacks comprehensive physiological measures such as body temperature, lactate, and cortisol levels. Including these factors is crucial for understanding the intricate link between cognition and physiology, as they can provide insights into how physiological states influence cognitive performance (Edholm et al., 2014; Hammami et al., 2018). Second, the inclusion of playing positions due to the sample size (n = 11 in CG and n = 11 in EG). Each playing position imposes unique physical and cognitive demands on soccer players, potentially leading to varied outcomes (Rampinini et al., 2008). Third, the level, age, and expertise of the soccer players were not considered, which are important factors that influence performance outcomes (Huijgen et al., 2013). Future research should incorporate these variables to provide a more comprehensive understanding of the effects of re-warm-up protocols.

Regarding the practical implications of the present study, we can suggest that an RWU should be implemented after half-time and before the start of the match. In addition, the PVT could be used to control the basal level of vigilance of each player. Given the increasing competitiveness in modern soccer, assembling a professional multidisciplinary team that includes a sports data scientist with expertise in neuroscience could enhance the management of actions requiring high levels of attention, which are critical to game performance. These findings highlight the importance of integrating RWU strategies within the broader context of player performance management.

Conclusions

The primary findings of this study demonstrated that a 7-min RWU after half-time improved RTs. Accordingly, implementing RWU protocols after half-time may enhance RT performance in the second half of the competition, providing a better vigilance indicator, which is crucial for avoiding goals.

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Conflict of interest

The authors report no conflict of interest.

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