วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 24 ฉบับที่ 2, ธันวาคม 2567
Journal of Sports Science and Technology Volume 24, No. 2, 2024

Original article

# THE EFFECTS OF A SUBSTITUTE IN GAME RE-WARM UP PROTOCOLS ON PERFORMANCE MEASURES IN SOCCER PLAYERS

Autsada TRAIPERM, Chris MAWHINNEY, Kotchakorn JUMROENKETPRATHEEP and Saiphon KONGKUM
*College of Sports Science and Technology, Mahidol University, Nakhon Pathom, THAILAND*

---

## ABSTRACT

This study aimed to compare the effect of two different re-warm-up (RW) protocols on selected performance outcomes in professional soccer players. Thirteen male professional soccer players (age: 21.1±0.8 years; height: 1.77±0.04 m; weight: 67.7±6.3 kg; BMI: 22.3±1.8 kg•m$^{2}$; $VO_{2max}$: 48±1.7 ml•kg$^{-1}$•min$^{-1}$) were recruited to take part in this study. In a randomized counterbalanced crossover fashion, participants completed a simulated substitute soccer routine involving a 20-minute warm-up and 40-minute passive rest followed by either a 2-minute high-intensity interval RW (HI-RW) at 90% $VO_{2max}$ interspersed with 30% $VO_{2max}$, or a 3-minute continuous low-intensity RW (LO-RW) at 30% $VO_{2max}$, both performed on a cycle ergometer. Countermovement jump (CMJ) flight time with simultaneous assessment of quadriceps muscle activation using electromyogram (EMG) activity, running anaerobic sprint test (RAST) indices, and ratings of perceived exertion (RPE) were measured after the 20-minute warm-up (pre) and post RW timepoints. No significant condition x time interaction was observed for CMJ flight time ($p = 0.465$) or quadriceps EMG activity in the rectus femoris ($p = 0.263$), vastus lateralis ($p = 0.129$), and vastus medialis ($p = 0.262$). Similarly, there was no significant interaction effect found for RAST indices (all $p>0.05$) or RPE ($p = 0.355$). It is concluded that both HI-RW and LO-RW protocols exerted comparable effects on the measured physiological and performance parameters in soccer players. However, due to the practical advantage of using a 2-minute HI-RW due to the protocol being more time efficient, and thus, more ecologically valid during substitution scenarios, completion of a HI-RW may be considered a more suitable RW option for in-game substitutes.

(Journal of Sports Science and Technology 2024; 24(2):36-46)
(Received: 3 May 2024, Revised: 9 December 2024, Accepted: 12 December 2024)

KEYWORDS: RAST/ muscle activation/ half-time/ CMJ/ intermittent team sports

*Corresponding author: Saiphon KONGKUM
College of Sports Science and Technology, Mahidol University, Nakhon Pathom, THAILAND
E-mail address: saiphon.kon@mahidol.ac.th

## INTRODUCTION

Soccer is characterized by alternating periods of high intermittent interval activity[1] over the duration of the match that can be characterized into specific movement patterns, for example multi-directional running and sprinting with rapid changes of direction, or jumping[2]. In particular, repetitive high-intensity runs expose the player to a significant physiological stress [3], resulting in central and peripheral fatigue which can markedly hinder the ability to maintain optimal performance during the match [3]. Therefore, in alignment with the regulations of the sport, substitutions are frequently introduced to offset any detrimental performance outcome (or injury exposure) associated with not withdrawing fatigued players. Currently, the English Football League allows the use of up to five substitutions from a preselected group of seven players[14]. Substitutions are typically planned after a break or towards the end of the game, taking into account not only physical fatigue but also in-game strategic changes or the inclusion of promising talents or recovering (post injury) athletes [14]. Indeed, empirical data from top-tier leagues including the English Premier League, Italy's Serie A, and Spain's La Liga, demonstrate that the average time for making the first to third substitutions typically occurs between the 57th and 81st minute of the game[14]. However, it is often the case that circumstances such as contact and non-contact injuries or player sendings off (red card) require earlier substitutions and or player tactical changes. Nevertheless, in the majority of cases, the first substitutions can be observed to occur around the halftime break, with other changes common after the 70th minute[4], when the magnitude of player fatigue is substantially elevated.

While substitutes participate in pre-match warm-up alongside the starting eleven players, upon match commencement, the players engage in only occasional preliminary activities near the halfway line and corner flag[3]. The interval between the warm-up and the commencement of the match can be lengthy as the game proceeds into second half. Therefore, entering the pitch with this condition may negatively impact a substitute's performance and increase the risk of injury[16]. Accordingly, a pre-match warm-up before a substitute enters the field of play is important to adequately prepare players for the demands of the game to offer a performance benefit,[5] with inadequate preparations requiring an initial period of in-game involvement for adaptation, rather than performing at expected levels of intensity[9]. Studies reporting a 15-minute period of inactivity can cause physiological changes that may reduce subsequent physical performance, such as repeated sprint ability or countermovement jumping [7,8]. This reduction of performance can likely be attributed to a decrease in body/muscle temperature. Therefore, it is considered essential for substitutes to engage in a re-warm-up before entering the pitch [8-10].

In recent years, the utility of a re-warm-up during the half-time interval of a soccer game has been extensively investigated[9-11]. An additional warm-up is effective in preventing decreases in sprint, jump, and endurance exercise performance by helping to maintain or increase muscle temperature, core temperature, muscular activation, and oxygen delivery to the muscles [8-10]. Taken together, these studies suggest a re-warm-up of moderate intensity lasting 5 to 7 minutes can help limit the decline in performance after a period of rest [5,7-10]. Nevertheless, this approach is only feasible during the halftime and may not be suitable when making during-game player changes. As a result, there has become a growing interest in

The aim of this study was to compare the effect of High (HIGH-RW) and Low (LOW-RW) in-game simulated substitute re-warm-up protocols on physiological and performance measures in professional soccer players. It was hypothesized that these two re-warm up protocols would differently alter physiological and performance measure in professional football player.

## METHODS

### Participants

In this randomized crossover designed study, thirteen male professional soccer players (age: 21.1 ± 0.8 years; height: 1.77 ± 0.04 m; weight: 67.7 ± 6.3 kg; BMI: 22.3 ± 1.8 kg/m²; $VO_{2max}$: 48 ± 1.7 ml/kg/min) were recruited. Participants had to meet the following inclusion and exclusion criteria: male football players (aged between 18-25 years) affiliated to a professional soccer team; consistently trained at least 3 day/week (≥ 2 hr. / day) for at least 1 year; no recent history of illness, injury or rehabilitation prior to experimental testing; not had surgery within 6 months prior to commencement of experimental testing, absence of health/disease conditions that may negatively affect the ability to perform test procedures. Given the constraints of limited access to professional soccer players, a sensitivity analysis was conducted to determine the interaction effect size that can be reliably detected with a sample size of 13 subjects, assuming a power of 0.8 and a significance level ($\alpha$) of 0.05. The study design is an analysis of covariance (ANCOVA) with one covariate, focusing on the interaction effect between group and time (pre-post measures). The sensitivity analysis indicates that the smallest detectable effect size (f) for the interaction in this design is 0.86, corresponding to a large effect size. This effect size reflects the magnitude of the group × time interaction, adjusted for baseline differences. The study was approved by The Ethics Committee for Human Research at Mahidol University (MU-CIRB 2021/085/1602).

### Procedure

<u>First visit</u>: Personal information and baseline anthropometry data, including age, height (cm), body mass (kg) and body mass index ($kg{\cdot}m^2$) were recorded. Participants performed a 30-m sprint test and a maximal voluntary isometric contraction (MVIC) of the knee extensors for collection of reference values for later tests. A graded exercise test (GXT) on a cycle ergometer Ahcten et al. (2002)[18] was also performed to determine $VO_{2max}$ corresponding to the individual work rate required during the RW conditions. The cycle test started at 95 W for 3 minutes before increasing by 35 W every 3 minutes until volitional exhaustion was attained (indicated when cadence fell below the target 60 rpm). Breath-by breath expired gas analysis measurements were collected using an automatic online gas analysis system (Cortex METALYZER®3B, Leipzig, Germany). Linear regression was employed to plot $VO_2$ against work rate (W) and was used to calculate the individual exercise intensity required at 90% $VO_{2max}$, and 30% $VO_{2max}$ during the two RW conditions. After a period rest (after VO2max test) participants were familiarized with the warm-up routine protocols.

<u>Second and Third visits:</u> Participants were asked to abstain from alcohol and caffeine and to avoid vigorous exercise for 24 hours prior to experimental testing. The participants were also asked to keep a food diary record over the 24 hours before each experiment and repeat their food intake on their subsequent visit. Participants were asked not to consume anything other than water for 3 hours before each experimental condition. Upon arrival, participants were asked to sit quietly while heart rate, blood pressure, and ratings perceived of exertion (RPE) were recorded. As previously described Van den Tillaar et al. (2016)[25], participants then performed a warm-up routine for 20 minutes followed by pre-test measures, including a countermovement jump (CMJ) with simultaneous electromyography (EMG) recordings of the quadriceps muscles, and a running anaerobic sprint test (RAST). Countermovement jump performance was measured using a force plate (Kistler Instrument AG, Switzerland). Participants were asked to stand quietly on the force plate and place hands on their hips. The participants then lowered into a squatting position, before instantaneously transitioning to propel their body upwards into the air. Flight time was recorded and was used to indicate lower body muscle power.

The test was performed twice, and the highest value was used for data analysis. Electromyography (FreeEMG 100 RT, BTS Bioengineering, Italy) was used to measure quadriceps muscle activation. In accordance with SENIAM guidelines, electrodes were placed on the right rectus femoris, vastus medialis and vastus lateralis to measure muscle activity during the countermovement jump. EMG signals were recorded and filtered and amplified at 10–500 Hz. The EMG signal was normalized to the EMG activity recorded during a maximal isometric knee extension (performed 1$^{st}$ visit). Next, the participants were asked to sit passively for 40-minutes on a chair before performing the re-warm up protocol. The HI-RW trial was performed at a cycling work rate corresponding to 90% $VO_{2max}$ and consisted of 3 blocks of 10 seconds work alternated with 30 seconds work corresponding to 30% of $VO_{2max}$ for a total work duration of 2 minutes. In the LO-RW trial, participants were asked to perform continuous cycling (which was work matched to the HI-RW trial) at a work rate corresponding to 30% of $VO_{2max}$ for 3 minutes. Upon completion of the re-warm-up protocol in each condition, the CMJ, EMG, and RAST measures were repeated (post-test). The experimental design is displayed in Figure 1.

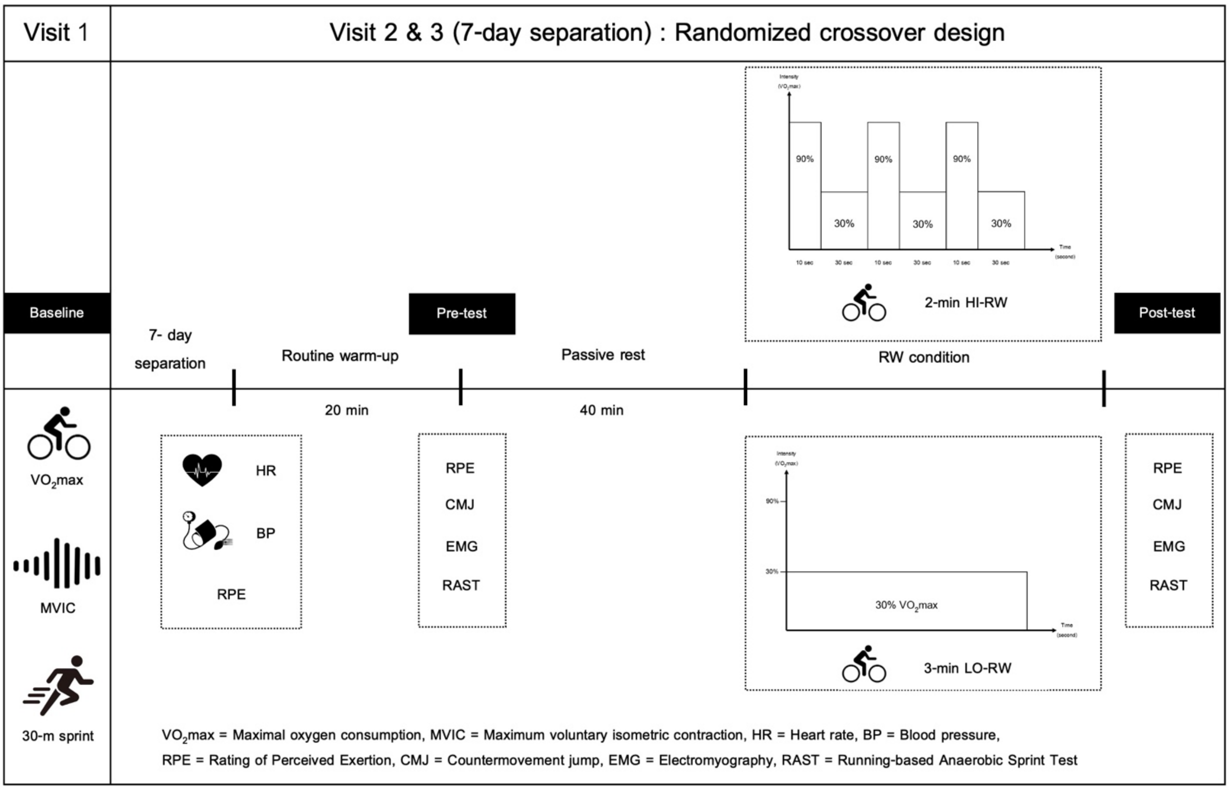


Figure 1. Schematic of the experimental procedure.

## Data Analysis

The normality of the residuals was checked using Shapiro-Wilk tests and Quantile-Quantile (Q-Q) plots. Baseline (pre-test values) were used as covariates to account for initial individual difference in outcome measures between conditions. As we employed a pre-post test design [Group (HI-RW, LO-RW); Time (Pre, Post)] we performed an Analysis of Covariance (ANCOVA) for CMJ flight time, RPE, EMG activity, and RAST measures, including fatigue index, maximum power, anaerobic power, average power, and anaerobic capacity. The assumption of homogeneity of regression slopes was tested and met. Our primary focus was on the interaction effect (Group x Time), which assessed whether the changes between pre and post measures differed between conditions. Where significant interaction effects were found, post-hoc pairwise comparisons with a Holm-Bonferroni correction were applied. Estimated marginal means and 95% confidence intervals (95% CI's) were interpreted to assess differences at the post time point, and adjusted for pre-test values. Partial $\eta^2$ values are also reported and classified as small (0.01–0.059), moderate (0.06–0.139), and large ($\geq$0.14; Cohen, 1988). The significance level was set at $P < 0.05$. All analyses were conducted using jamovi software (The jamovi project, 2023).

## RESULTS

***Performance measures***

*Countermovement jump flight time*

CMJ flight time data did not demonstrate a statistically significant condition x time interaction effect ($F_{(1,47)} = 0.54$, $p = 0.465$; $\eta^2 p = 0.01$; Table 1). CMJ flight times generally remaining unchanged from the pre-test to post-test ($F_{(1,47)} = 0.017$, $p = 0.898$; $\eta^2 p = 0.01$, Table 1) timepoints, respectively.

*Running Anaerobic Sprint Test (RAST)*

*Average Power*

The interaction effect between condition x time for RAST average power was not statistically significant ($F_{(1,47)} = 2.22$, $p = 0.143$; $\eta^2 p = 0.04$; Table 1). There was also no statistically significant main effect of time ($F_{(1,47)} = 0.798$, $p = 0.376$; $\eta^2 p = 0.02$) with average power values remaining similar across timepoints (Table 1).

*Maximum Power*

There was no statistically significant interaction effect for maximum power ($F_{(1,47)} = 0.21$, $p = 0.648$; $\eta^2 p = 0.01$; Table 1). The main effect of time was also not statistically significant ($F_{(1,47)} = 1.27$, $p = 0.266$; $\eta^2 p = 0.03$; Table 1) with no change in maximum power across the pre to post-test timepoints (Table 1).

*Anaerobic Capacity*

The ANCOVA analysis for anaerobic capacity revealed no statistically significant condition x time interaction effect ($F_{(1,47)} = 0.61$, $p = 0.440$; $\eta^2 p = 0.01$; Table 1). Similarly, there was no statistically significant time effect, with anaerobic capacity remaining unchanged between pre and post-test time points ($F_{(1,47)} = 0.031$, $p = 0.862$; $\eta^2 p = 0.00$; Table 1).

*Fatigue Index*

For fatigue index, no statistically significant interaction effect was noted between condition x time ($F_{(1,47)} = 0.015$, $p = 0.902$; $\eta^2 p = 0.00$; Table 1). In addition, there was also no statistically significant main effect for time, with the change in fatigue index remaining similar across the pre and post-test timepoints ($F_{(1,47)} = 2.16$, $p = 0.148$; $\eta^2 p = 0.04$; Table 1).

**Table 1.** Estimated marginal means for performance variables across the interaction of Condition and Time.

| Variable | Condition | Time | Estimated Marginal Mean | 95% CI | $\eta^2 p$ |
|---|---|---|---|---|---|
| *Performance Measures* | | | | | |
| CMJ Flight Time (*s*) | HI-RW | Pre | 0.52 | 0.52, 0.53 | 0.01 |
| | | Post | 0.52 | 0.52, 0.53 | |
| | LOW-RW | Pre | 0.53 | 0.51, 0.53 | |
| | | Post | 0.53 | 0.52, 0.54 | |
| RAST Average Power (W) | HI-RW | Pre | 496 | 473, 519 | 0.04 |
| | | Post | 469 | 445, 492 | |
| | LOW-RW | Pre | 495 | 472, 518 | |
| | | Post | 501 | 479, 525 | |
| RAST Maximum Power (W) | HI-RW | Pre | 582 | 506, 659 | 0.01 |
| | | Post | 642 | 566, 719 | |
| | LOW-RW | Pre | 584 | 507, 660 | |
| | | Post | 609 | 533, 686 | |
| RAST Anaerobic Capacity (W) | HI-RW | Pre | 2902 | 2770, 3034 | 0.01 |
| | | Post | 2942 | 2810, 3074 | |
| | LOW-RW | Pre | 2902 | 2770, 3034 | |
| | | Post | 2839 | 2707, 2971 | |
| Fatigue Index (W•*s*) | High-RW | Pre | 6.74 | 4.82, 6.85 | 0.00 |
| | | Post | 5.45 | 3.54, 7.37 | |
| | LOW-RW | Pre | 6.89 | 4.97, 8.80 | |
| | | Post | 5.37 | 3.45, 7.29 | |

CMJ, Countermovement Jump; RAST, Running Anaerobic Sprint Test

***Physiological measures***

*Electromyography (EMG)*

For EMG activity of the rectus femoris muscle, there was no statistically significant interaction effect observed ($F_{(1,43)}$ = 1.285, p = 0.263; $\eta^2 p$ = 0.01; Table 2). Similarly, no main effect of time was found for EMG activity ($F_{(1,43)}$ = 0.200, p = 0.657; $\eta^2 p$ = 0.00; Table 2), with percentage values remaining unchanged across the pre to post-test timepoints.

There was no statistically significant interaction found for EMG vastus lateralis activity ($F_{(1,43)}$ = 2.40, p = 0.129; $\eta^2 p$ = 0.05; Table 2). In addition, there was no main effect of time observed ($F_{(1,43)}$ = 1.545, p = 0.221; $\eta^2 p$ = 0.04; Table 2) with similar EMG activity values noted at across pre and post-test timepoints.

The interaction effect between condition x time for EMG vastus medialis activity was not statistically significant ($F_{(1,43)}$ = 1.29, p = 0.262; $\eta^2 p$ = 0.03; Table 2). There was also no statistically significant main effect of time ($F_{(1,43)} = 1.096$, $p = 0.301$; $\eta^2p = 0.02$) with EMG vastus medialis values remaining similar across timepoints (Table 2).

*Ratings of Perceived Exertion (RPE)*

There was no significant condition x time interaction effect found for RPE scores ($F_{(1,47)} = 0.87$, $p = 0.355$; $\eta^2p = 0.02$; Table 2). However, a significant main effect of time effect ($F_{(1,47)} = 53.29$, $p < 0.001$; $\eta^2p = 0.53$) was observed, with higher RPE scores generally recorded at the post timepoint compared with pre values (Table 2).

**Table 2.** Estimated marginal means for physiological variables across the interaction of Condition and Time.

| Variable | Condition | Time | Estimated Marginal Mean | 95% CI | $\eta^2p$ |
|---|---|---|---|---|---|
| *Physiological Measures* | | | | | |
| EMG Rectus femoris (%max) | HI-RW | Pre | 105.37 | 89.56, 121.18 | 0.01 |
| | | Post | 92.99 | 77.18, 108.80 | |
| | LOW-RW | Pre | 103.50 | 87.69, 119.31 | |
| | | Post | 108.87 | 93.06, 124.68 | |
| EMG Vastus Lateralis (%max) | HI-RW | Pre | 95.61 | 85.43, 105.80 | 0.05 |
| | | Post | 81.52 | 71.34, 91.70 | |
| | LOW-RW | Pre | 94.94 | 84.75, 105.12 | |
| | | Post | 96.48 | 86.30, 106.67 | |
| EMG Vastus Medialis (%max) | HI-RW | Pre | 137.50 | 120.38, 154.61 | 0.03 |
| | | Post | 136.74 | 119.62, 153.86 | |
| | LOW-RW | Pre | 137.60 | 120.49, 154.72 | |
| | | Post | 156.09 | 138.97, 173.20 | |
| RPE (a.u.) | HI-RW | Pre | 11.31 | 10.39, 12.23 | 0.00 |
| | | Post | 8.39 | 7.47, 9.31 | |
| | LOW-RW | Pre | 11.66 | 10.73, 12.58 | |
| | | Post | 7.88 | 6.95, 8.80 | |

EMG, Electromyography; RPE, Ratings of Perceived Exertion

## DISCUSSION

The purpose of this study was to investigate the effects of two substitute RW conditions on performance measures using an ecologically valid simulation of inactivity to that experienced by substitute soccer players. The main findings revealed that there was no marked difference in performance (CMJ, RAST indices) or physiological (muscle activation, RPE) measures between the HI-RW and LO-RW conditions. Our data suggests that performing higher intensity activity does not result in any benefit on substitute performance compared with completion of lower intensity continuous exercise that is work-matched.

In the present study, we observed no marked differences across measured RAST indices between HI-RW and LOW-RW conditions. It is expected that increasing core and muscle temperatures can influence muscle activation via upregulating enzymatic processes that lead to a higher rate of muscle contraction and a lower time to peak tension [11]. Mohr et al. (2004) [4] reported moderate-intensity RW at ~70% of maximal heart rate for 5 minutes improved both sprint and repeated sprint ability when core and muscle temperatures attained 38.1°C and 39.4 °C, respectively. The aforementioned can be deemed beneficial to soccer performance where repeated sprint bouts (high-speed running) of 2-4 seconds generally occurs every 90 seconds,[21] accounting for 1-11% of the total distance performed in a match, and is a predictor of attaining a successful match outcome [4]. Indeed, a marked reduction in the amount of high-intensity running during the final 15 minutes of a second half, is associated with a reduction in anaerobic capacity [10]. However, in the present study, we did not record any significant difference in repeated sprint performance (i.e., CMJ flight time, RAST maximum power, average power; Table 1) or anaerobic capacity (and fatigue index; Table 1) between the HI-RW and LOW-RW conditions. Although difficult to ascertain without additional thermoregulatory measures, it may be speculated that as the two RW conditions were work-matched, core and muscle temperatures may have been elevated to a similar extent, resulting in similar physiological and performance responses. In combination of finding no differences in EMG activity across the individual rectus femoris, vastus lateralis, and vastus medialis quadriceps muscles (Table 2), our findings may be extrapolated to suggest that performing a HI-RW warm-up does influence neuromuscular activation compared with performing a work-matched LOW-RW, or provide any additional benefit to repeated sprint performance.

Despite not observing any direct evidence of an enhanced lower body muscle activation in the HI-RW condition in our study, it has previously been demonstrated that engaging in a HI-RW can enhance voluntary muscle contractions and performance during a later part of subsequent activity. This phenomenon is known as post-activation potentiation (PAP) [19]. The impact of a HI-RW and the resultant PAP effect on sprint performance from performing five-repetition maximal leg press RW being shown to increase subsequent sprint performance [11]. It is possible that as opposed to the cycle ergometer RW exercise used in our study, sport specific movements are required to increase the neuromuscular drive to the lower body musculature to result in benefits in soccer performance measures. At half-time, active RW strategies including PAP and multi-directional speed drills [7] have been recommended for a duration of 5-7 min for maintaining exercise performance [5,7,8], and may be a focus for future work employing high-intensity, short duration substitute RW protocols. In addition, few studies have investigated the effects of acute RW protocols on CMJ performance. Similar to our observations, Patti et al. (2022) [28] reported a short duration RW with high-intensity exercise consisting of 3 maximum sprints over a 60 m distance did not improve vertical jump height performance.

A number of limitations our associated with the current study. Firstly, we did not record core or muscle temperatures, which could have provided insight into thermoregulatory changes associated performing the HI-RW and LOW-RW interventions. Additionally, due to budget constraints, we also did not record lactate levels to assess the anaerobic contribution during the RAST tests. Such data may have highlighted differences in residual fatigue during subsequent performance tests. While we normalized EMG activity to maximal muscle activation (MVIC) during an isokinetic dynamometer test, in some cases, %EMG exceeded the maximum value recorded during the CMJ task for individual quadriceps muscles. Future work should consider recording muscle activity during isokinetic MVIC's to better align maximum EMG values with the performance task. Finally, the RW protocols used in this study involved cycling, which, while controlled, lack specificity to the diverse movement patterns in most intermittent sports. Activities such as running, jumping, and multidirectional movements are integral to soccer, and their absence in our intervention protocols may have limited the magnitude of performance changes observed. Future studies may consider comparisons of sport-specific RW protocols to better reflect the demands and physiological responses or real-world scenarios.

In conclusion, this study provides insights into the effects of substitute re-warm up intensity on performance and physiological responses in soccer players. The lack of significant differences between HI-RW and LOW-RW protocols suggest that a lower intensity, work-matched approach, may be equally effective in maintaining performance during substitute scenarios. These findings emphasize the importance of practicality and feasibility when designing re-warm up strategies for substitute players, particularly given the logistical constraints of match settings. Future research should explore the inclusion of sport-specific movements and the potential influence of re-warm up protocols on longer-term performance outcomes.

## REFERENCES

1. Hills SP, Barwood MJ, Radcliffe JN, Cooke CB, Kilduff LP, Cook CJ, et al. Profiling the responses of soccer substitutes: A review of current literature. Sports Med. 2018; 48:2255–69. https://doi.org/10.1007/s40279-018-0962-9
2. Bishop, D. Warm up ii: Performance changes following active warm up and how to structure the warm up. Sports Med. 2003; 483–498. doi:10.2165/00007256- 200333070-00002
3. McMillian, D. J., Moore, J. H., Hatler, B. S., & Taylor, D. C. Dynamic vs. static-stretching warm up: the effect on power and agility performance. J Strength Cond Res.2006, 20(3), 492-499.
4. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 2003;21(7):519-28.
5. Russell M, West DJ, Harper LD, Cook CJ, Kilduff LP. Half-time strategies to enhance second-half performance in team-sports players: a review and recommendations. Sports Med. 2015;45(3):353-64.
6. Mohr, M., Krustrup, P., & Bangsbo, J. (2005). Fatigue in soccer: a brief review. J Sports Sci.2005;23(6), 593-599.
7. Hammami A, Zois J, Slimani M, Russell M, Bouhlel E. The efficacy, and characteristics, of warm-up and re-warm-up practices in soccer players:a systematic review. J Sports Med Physi Fit. 2018.
8. Silva, L. M., Neiva, H. P., Marques, M. C., Izquierdo, M., & Marinho, D. A. Effects of warm-up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review. Sports Med.2018;48(10), 2285-2299.
9. Yanaoka T, Hamada, Y, Kashiwabara, K, Kurata, K, Yamamoto, R,Miyashita, M, and, Hirose N. Very-short-duration, low-intensity half-time re-warm up increases subsequent intermittent sprint performance. J Strength Cond Res.2018; 32, 3258–3266. doi: 10.1519/JSC.0000000000002781
10. Yanaoka, T., Hamada, Y., Fujihira, K., Yamamoto, R., Iwata, R., Miyashita, M., et al. High-intensity cycling Re-warm up within A very short time-frame increases the subsequent intermittent sprint performance. Eur. J. Sport Sci. 2020, 1307–1317. doi:10.1080/17461391.2020.1713901
11. Yanaoka, T., Kashiwabara, K., Masuda, Y., Yamagami, J., Kurata, K., Takagi, S., ... & Hirose, N. The effect of half-time re-warm up duration on intermittent sprint performance. J. sports sci & med.2018, 17(2), 269.
12. Yanaoka, T., Iwata, R., Yoshimura, A., and Hirose, N. (2020b). A 1-minute Rewarm up at high-intensity improves sprint performance during the Loughborough intermittent shuttle test. Front. Physiol. 11, 616158. doi:10. 3389/fphys.2020.616158

13. Mohr, M., Krustrup, P., Nybo, L., Nielsen, J. J., & Bangsbo, J. Muscle temperature and sprint performance during soccer matches–beneficial effect of re-warm-up at half-time. Scand J. Med & Sci Sports.2004, 14(3), 156-162.

14.Lovell, R. J., Kirke, I., Siegler, J., McNaughton, L. R., & Greig, M. P. Soccer half-time strategy influences thermoregulation and endurance performance. J of sports med and physical fitnes.2007, 47(3), 263.

15. Bishop D. Warm up I : potential mechanisms and the effects of passive warm up on exercise performance. Sports Med. 2003;33(6):439-54.

16. McGowan, Courtney J., et al. "Warm-up strategies for sport and exercise: mechanisms and applications." J.Sports med. 2015,45: 1523-1546.

17. López-Valenciano, A., Moreno-Perez, V., Campo, R. L. D., Resta, R., & Coso, J. D. The Five-substitution Option Enhances Teams' Running Performance at High Speed in Football. Int J Sports Med.2023, 44(05), 344-351.

18. Achten, J., Gleeson, M., & Jeukendrup, A. E.. Determination of the exercise intensity that elicits maximal fat oxidation. Med & Sci sports and exercise.2006, 34(1), 92-97.

19. Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjær, M., & Bangsbo, J Muscle and blood metabolites during a soccer game: implications for sprint performance. Med & Sci sports and exercise.2006,38(6), 1165-1174.

20. Hills, S. P., Barrett, S., Hobbs, M., Barwood, M. J., Radcliffe, J. N., Cooke, C. B., & Russell, M. Modifying the pre-pitch entry practices of professional soccer substitutes may contribute towards improved movement-related performance indicators on match-day: A case study. PloS one.2020.15(5), e0232611.

21. Edholm, P., Krustrup, P., & Randers, M. B. Half-time re-warm up increases performance capacity in male elite soccer players. Scand J.Med & Sci in sports.2015, 25(1), e40-e49.

22. Chmura, P., Konefał, M., Chmura, J., Kowalczuk, E., Zając, T., Rokita, A., & Andrzejewski, M. Match outcome and running performance in different intensity ranges among elite soccer players. Biol sport.2018;35(2), 197-203.

23. Blazevich, Anthony J., % Babault N. Post-activation potentiation versus post-activation performance enhancement in humens: historical perspective, underlying mechanisms, and cirrent issues.Fronts. Physiol. 2019,10:1359.

24. Bishop,D. Warm up I; potential mechanisms and effects of passive warm up on exercise performance. Sports Med.2006.33,439-454

25. Faude,O ., Koch, T.,& Meyer, T. Stringht sprinting is the most frequent action in goal situations in professional football. J sports sci.2012. 30(7), 625-631.

26. Van den Tillaar, R., & von Heimburg, E. Comparison of two types of warm-up upon repeated-sprint performance in experienced soccer players. J.Strength Cond. Res.2016.30(8), 2258-2265.

27. Bangsbo, J, Mohr,M, and Krustrup P. "Physical and metabolic demands of training and match-play in the elite football player." J Sports Sci.2006, 24.07: 665-674.

28. Patti A , Giustino V, and Hirose N. Effects of an experimental short-time high-intensity warm-up on explosive muscle strength performance in soccer players: A pilot study. Front. Physiol. 2022. 13:984305

29. Güllich, A., & Schmidtbleicher, D. MVC-induced short-term potentiation of explosive force. New studies in athletics. 1996, 11, 67-84.

30. Gonzalez F,Samento H, Infantes-Paniagua A. Effects of rewarm-up protocols on the physical performance of soccer players: A systematic review with meta-analysis. Biol Sport. 2023;40(2):335–344.

31. Stewart, D., Macaluso, A., & De Vito, G. The effect of an active warm-up on surface EMG and muscle performance in healthy humans. Eur J Appl Physiol. 2003, 89, 509-513.