

Ten-minute warm-up in hot climate best assists thermal comfort, muscular power output, and fatigue, during soccer-specific repeated-sprint ability

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ABSTRACT: Structuring warm-up (WU) in hot climate conditions before high-intensity efforts is still drawing the attention of researchers and practitioners. The present study investigates the effect of two WU durations (i.e. 10 min: WU10 and 20 min: WU20) in a hot climate (~31°C), on thermal comfort, muscular power output and fatigue after a repeated-sprint test (RSA) in soccer players. Twelve amateur soccer players (age = 21.13 ± 1.8 years; height = 172.5 ± 4.6 cm and weight = 70.8 ± 5.1 kg) participated in a cross-over randomized study, and they underwent a soccer-specific RSA test, after two WU durations and on different days. Peak power (PP), mean power (MP) and the fatigue index (FI) were calculated and analysed. Likewise, thermal comfort/discomfort (TC), tympanic temperature (T_{tym}) and rating of perceived exertion (RPE) were recorded at rest, after WU and after RSA. The ANOVA showed a significant increase in MP after WU10 in comparison to WU20 by 1.9%, while PP remained similar between the two durations. A significant decline in muscular power in WU20 compared to WU10 appeared from the 5th sprinting repetition and continued to the end of the RSA. The WU20, compared to the WU10, produced higher RPE at post-WU ($p < 0.001$) and post-RSA ($p = 0.018$), and higher thermal discomfort sensation in both post-WU ($p = 0.022$) and post-RSA ($p = 0.007$) point of measures. Larger increases in T_{tym} were recorded after WU20 compared to WU10. WU10 in a hot climate (~31°C) best assists mean power output during soccer RSA, but not peak power. Extending the WU duration up to 20 min in a hot climate was revealed to be detrimental for muscular power output, inducing excessive thermal discomfort and fatigue. Therefore, it is important that trainers and soccer players carefully consider WU duration prior to competitions and training sessions in a hot climate, to optimize physiological responses.

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INTRODUCTION

Several competitive events are held in hot climate conditions, such as the last Olympic Games in Brazil 2016, the last World Athletics Championship in Doha 2019 and the forthcoming soccer World Cup in Qatar 2022, imposing an additional stress on participants [1]. It has been shown that heat stress results in high body temperatures, negatively affects physical performances in soccer and accelerates the fatigue process [2].

Structuring warm-up (WU) in those challenging climatic conditions is still essential in athlete pre-effort routines [3, 4]. Indeed, in the last decade, the attention of researchers was focused on the effect of WU duration, conducted in moderate climate conditions, on short-term maximal performances, performed at different times of day [5, 6], with or without a rest interval following the WU [7, 8], and among different fitness levels of participants [9]. Recently, it was demonstrated that 8 min WU better improves acceleration and sprint performances in comparison to 15 and 25 min WU among soccer

players [10]. Others compared the effect of long and short WU (20 vs 10 min) upon repeated-sprint performance in soccer players, and concluded that the short warm-up is as effective as the long one for repeated-sprint ability in soccer [11].

To the authors' best knowledge, the effect of WU procedures, in a hot climate, is still little studied and needs more investigations. Indeed, a recent review study [3] recommended, according to the RAMP model of Jeffreys [12], reducing the WU duration for prolonged, intermittent and intermediate exercises, conducted in the heat. Nonetheless, no study has focused on the effect of WU duration, in hot climate conditions, on soccer repeated-sprint ability (RSA). This performance (RSA), characterized by the production of maximal short-sprint bouts, with brief recovery in between (< 60 s) [13, 14], corresponds to one of the fundamental components of soccer competitions [15, 16], and it is assumed to be an essential indicator of in-match physical performance of fitness-based team sport [17].

While muscle temperature elevation is requested for maximal repeated-sprint performance in soccer, it was shown that this performance deteriorates with hyperthermia even though higher muscle temperatures are reached [2, 18]. Hyperthermia, defined as an excessive increase in core temperature above $\sim 37^{\circ}\text{C}$ at rest, and $\sim 38^{\circ}\text{C}$ during moderate intensity exercise, was shown to be responsible for both peripheral (muscular) and central fatigue (central nervous system) [19]. Recently, it was concluded that heat exposure increases thermal and circulatory strain [3] and leads to an increase in core temperature, which can result in a decrement in high-intensity running performances in female soccer players [20].

In view of the above considerations, the aim of the present investigation was to compare the effect of two warm-up durations (i.e. WU10 and WU20) in a hot climate, on thermal comfort, muscular power output, and fatigue after RSA in soccer players. We hypothesized that varying WU durations in a hot climate ($\sim 31^{\circ}\text{C}$) may affect differently thermal comfort/discomfort, muscular power output and fatigue during specific repeated-sprint effort in soccer players.

MATERIALS AND METHODS

Participants

Amateur soccer players ($N = 12$) volunteered to participate to the study and signed a consent form, after receiving a thorough explanation of the protocol, the benefits and risks involved (Table 1). All participants were free from injury and were affiliated in the senior (second division) A'Sharqiyah region soccer championship (Saudi Arabia). They had at least 5 years of training experience in soccer, with regularly training sessions (5 ± 2 sessions per week). In addition, and as they were physical education students, they undertook ~ 8 h/week of various physical activities as part of their university courses. We interviewed all students in order to provide information concerning the number of years of soccer practice and hours of regular training per week. During the experimental period, they were not specially trained for either endurance or sprinting. The study protocol complied with the ethical standards of the 1975 Helsinki Declaration and the protocol was fully approved by the local Scientific Ethic Committee.

TABLE 1: Characteristics of study participants

	Mean ($N = 12$)	SD	max-min
Age (years)	21.13	1.8	24.3–19.1
Height (cm)	172.5	4.6	180.5–166
Weight (kg)	70.8	5.1	78.6–63.6
BMI ($\text{kg}\cdot\text{m}^{-2}$)	23.8	1	25.2–21.9
YO-YO test distance (m)	2016	152.9	2240–1800
MAV (km/hr)	16.83	0.4	17.4–16.2

Experimental procedures

During the week preceding the experiment, participants became familiarized with the Bangsbo Sprint Test [16, 21] and the testing procedures. These familiarizations ensured that participants were fully knowledgeable of the experimental conditions and measurements required. The best sprint performed in the familiarization session was retained, and participants were requested to achieve at least 95% of the time of the first sprint during the testing sessions, otherwise they would be excluded. Such an instruction was imposed to avoid possible pacing during the test [22].

All testing sessions were conducted outdoors, on flat artificial turf, at the same habitual training time (i.e. 4:00–6:00 PM) and with at least 48 h of recovery in between to avoid the learning effect from session to session. Each test session began with 30 min of rest in a seated position and shaded place. After this period, resting heart rate (HR), rating of perceived exertion (RPE) and thermal comfort/discomfort (TC) were recorded using a heart rate monitor (Polar Electro Oy, S410, Hungary), the rating of perceived scale [23] and the comfort/discomfort scale [24]. Tympanic temperature (T_{tym}) was recorded using a digital thermometer (Braun Thermoscan IRT 6520 Germany, precision 0.1°C) according to Edwards et al. [25]. To avoid a drop in body temperature, a maximal rest interval of 5 min, between the end of the WU and the onset of the RSA, was allowed [7, 8]. After that, they performed, in a randomized order, one of the proposed WU: WU10 or WU20. The external temperature and humidity were controlled by a wireless temperature and humidity sensor (Thermo-hygro Oregon Scientific THGR122NX) and were set at $31.4 \pm 1.5^{\circ}\text{C}$ and $17.7 \pm 4.3\%$, respectively. The local Wet Bulb Globe Temperature was estimated at WBGT = 21.3 [26] characterizing the arid hot-dry environment of the eastern province of Saudi Arabia.

Rating of perceived exertion (RPE)

The rating of perceived exertion (RPE) was determined using the Borg scale [22] at rest, at the end of the WU (post-WU) and the end of the RSA (post-RSA). The scale matches how hard you feel you are working, according a 15-point scale ranging from 6 to 20. The scale starts with “no feeling of exertion”, which rates 6, and ends with “very, very hard”, which rates 20 on the scale. So the higher the score, the higher the RPE estimation.

Thermal comfort/discomfort (TC)

The thermal comfort/discomfort (TC) scale [24] represents determination about whether participants perceived their state in the category of “comfortable” or “uncomfortable”. The scale, matching a 5-point scale, starts with “very uncomfortable”, which rates -2, and ends with “very comfortable”, which rates +2.

Warm-up protocol

The WU protocol was structured according the Jeffreys [12] model. Each warm-up session began with a RAISE stage consisting of 5 or 15 min running at 70% of maximal aerobic velocity (Yo-Yo intermittent

recovery test Level_1) [27], followed by 4 min of dynamic stretching (DS; ACTIVATE and MOBILIZE) and 2 × 15 m maximal sprint repetitions (POTENTIATE). So the global WU durations were 10 and 20 min. Participants were instructed to perform the DS stretches at a rate of, approximately, 1 stretch cycle every 2 s. The DS exercises, adopted from previous research [28], involved active and slow movements, without bouncing of antagonist muscles and performed on alternate legs for 30 seconds, at a rate of approximately 1 stretch cycle every 2 seconds. The DS consisted of stretches that solicit the major muscle groups involved in maximal sprint: the gastrocnemius, hamstrings, quadriceps, hip flexors and the adductors. At the end of the WU, and for neural activation [3], participants were invited to sprint 2 × 15 m, with 25 s recovery in between [29].

Repeated-sprint ability test (RSA)

The RSA test [21], consisting of 7 repetitions of a distance of 34.2 m, was conducted according to a previous description [16]. Power in each sprint trial was calculated according the formulas of Keir et al. [29]: $Power = (body\ mass \times distance^2) / time^3$. Likewise, the fatigue index, corresponding to the percent in power decrement, was calculated according to the formula of Fitzsimons et al. [30]: $FI = [(TT/PT \times number\ of\ sprints - 1)] \times 100$, where TT is the total time and PT is the peak recorded time.

Statistical analysis

All statistical tests were processed using STATISTICA Software (Stat-Soft, France). Data distribution normality was confirmed by the Shapiro-Wilk W-test. Tympanic temperature (T_{tym}), rate of perceived exertion (RPE), thermal comfort (TC) and heart rate data were analysed using two-way ANOVA with repeated measures (3 WU duration × 2 measure). MP and PP were analysed using one-way ANOVA, while mean power per sprint trial was analysed using two-way ANOVA with repeated measures (3 WU duration × 7 sprint number). When appropriate, significant differences between means were assessed using the Bonferroni post-hoc test. Furthermore, the effect size “partial η^2 ” for significant main effects was calculated. Effect sizes were classified as small (0.1–0.3), medium (0.3–0.5), and large (> 0.5) [31]. Statistical significance was set at $p < 0.05$. The power of statistical tests was verified with the G*Power software version (3.1.9.2). Considering the sample size, the significance level of 5% and the partial effect size η^2 , the calculated power analyses (1- β) values were between 0.8 and 1.0 for all variables.

RESULTS

Heart rate (HR), rating of perceived exertion (RPE), and tympanic temperature (T_{tym})

HR, RPE, and T_{tym} values recorded during the different experimental conditions are presented in Table 2.

Concerning HR, the two-way ANOVA indicated a significant effect of both measure ($F = 842.312$; $p < 0.001$; $\eta^2 = 0.987$; large) and WU durations ($F = 26.651$; $p < 0.001$; $\eta^2 = 0.707$; large).

TABLE II: Heart rate (HR), rate of perceived exertion (RPE), and tympanic temperature (T_{tym}) values at rest, after the warm up (Post-WU) and at the end of the RSA-test (Post-RSA).

		WU10	WU20
HR (bpm)	Rest	68 ± 8***	67 ± 10***
	Post-WU	130 ± 10	143 ± 15†††
	Post- RSA	172 ± 13	179 ± 9
RPE	Rest	6.3 ± 0.5***	6.4 ± 0.5***
	Post-WU	9.4 ± 1.7	12.9 ± 0.8†††
	Post- RSA	16.3 ± 1.1	17.2 ± 0.6†
T_{tym} (°C)	Rest	36.1 ± 0.4	36.1 ± 0.3***
	Post-WU	36.4 ± 0.2	36.8 ± 0.2††

Values are mean ± SD; WU10: 10min warm up; WU20: 20min warm-up. * Significant difference between Post-WU and rest values at: * $p < 0.05$ ** $p < 0.01$; *** $p < 0.001$; † Significantly different than WU10 at the same point of measure at: † $p < 0.05$; †† $p < 0.01$; ††† $p < 0.001$;

The interaction (WU duration × measure) was significant too ($F = 7.896$; $p = 0.003$; $\eta^2 = 0.419$; medium). The post hoc analysis showed higher HR values recorded at the post-WU point of measure in WU20 sessions, compared to WU10 ($p < 0.001$).

Concerning the RPE, the two-way ANOVA indicated that the main effects of measure and WU durations were significant with ($F = 860.824$; $p < 0.001$; $\eta^2 = 0.987$; large) and ($F = 92.328$; $p < 0.001$; $\eta^2 = 0.893$; large), respectively. The interaction (WU duration × measure) was significant too ($F = 15.317$; $p < 0.001$; $\eta^2 = 0.582$; large). The post hoc analysis showed higher RPE estimations recorded in WU20 sessions and compared to WU10, at both post WU ($p < 0.001$) and post RSA ($p = 0.018$) point of measures.

Concerning the T_{tym} , the two-way ANOVA indicated that the main effect of measure was significant ($F = 24.105$; $p < 0.001$; $\eta^2 = 0.686$; large). However, the main effect of WU duration was not significant ($F = 3.366$; $p = 0.094$). The interaction WU duration × point of measure was significant ($F = 9.136$; $p = 0.012$; $\eta^2 = 0.454$; medium). The post hoc analysis showed no significant differences in rest point of measures ($p = 0.671$). However, after the WU procedures, higher T_{tym} values were recorded after WU20 compared to WU10 ($p = 0.016$).

Thermal comfort/discomfort (TC)

Concerning TC, the two-way ANOVA indicated that the main effects of measure and WU durations were significant ($F = 66.379$; $p < 0.001$; $\eta^2 = 0.857$; large and $F = 8.800$; $p = 0.013$; $\eta^2 = 0.444$; medium, respectively). The interaction (WU duration × measure) was significant too ($F = 6.217$; $p = 0.007$;

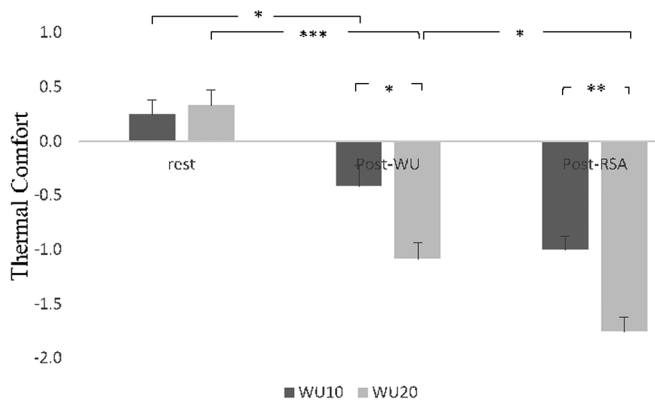


FIG. 1. Results (mean \pm SD) of thermal comfort/discomfort at WU10 and WU20 sessions, recorded at rest, after warm-up (post-WU) and after RSA (post-RSA).

Significant difference at: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

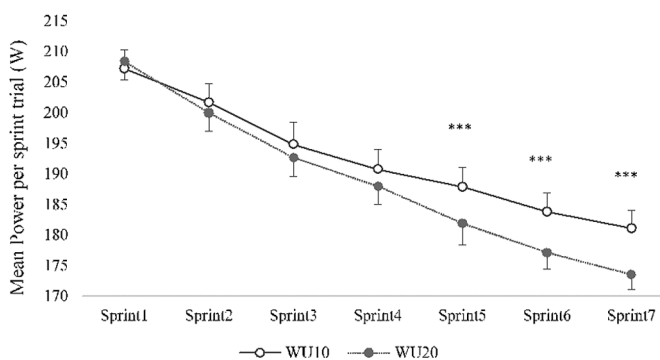


FIG. 2. Results (mean \pm SD) of muscular power-putput, recorded according to WU10 and WU20 durations and sprint repetitions.

* Significant difference at: *** $p < 0.001$.

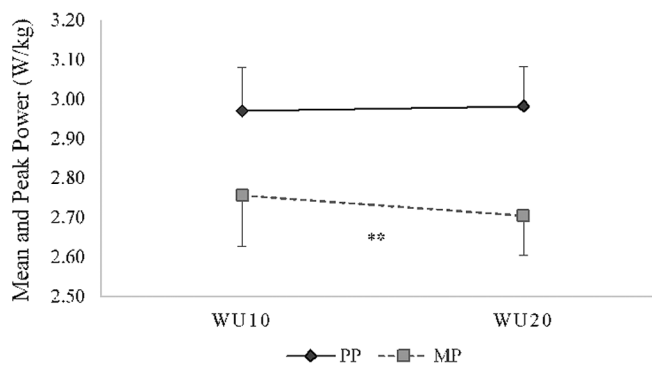


FIG. 3. Results (mean \pm SD) of mean (MP) and peak (PP) power, recorded according WU durations: WU10 and WU20.

* Significant difference at: ** $p < 0.01$.

$\eta^2 = 0.361$; medium). The post hoc analysis showed lower TC recorded at post-WU compared to rest values after both WU10 ($p = 0.023$) and WU20 ($p < 0.001$). TC values recorded at both post-WU and post-RSA point of measures were lower in WU20 compared to WU10 ($p = 0.023$ and $p = 0.007$, respectively).

Power output and fatigue index (FI)

Figure 2 illustrates the muscular power output, recorded according to WU durations and sprint repetitions.

Concerning the muscular power, the two-way ANOVA showed that the main effect of sprint repetition and warm-up duration were significant ($F = 369.868$; $p < 0.001$; $\eta^2 = 0.971$; large, and $F = 8.553$; $p = 0.014$; $\eta^2 = 0.437$; medium, respectively). The interaction WU duration \times 7 sprint repetitions was significant too ($F = 12.738$; $p < 0.001$; $\eta^2 = 0.536$; large). The post-hoc analysis showed no significant difference between the two WU durations in the first four sprints trials ($p > 0.05$ for all sprint comparisons). However, in the last three sprints, higher power-output was recorded after WU10 in comparison to WU20 ($p < 0.001$ for all sprint comparison).

Concerning peak power (W/Kg), the one-way ANOVA showed no effect of the variable duration ($F = 1.262$; $p = 0.285$). However, concerning mean power (W/Kg), the effect of duration was significant ($F = 8.295$; $p = 0.015$; $\eta^2 = 0.430$; medium). The post-hoc analysis showed higher MP values recorded after WU10 compared to WU20 ($p = 0.015$).

Concerning the fatigue index FI, the one way ANOVA showed significant effect of the variable duration ($F = 33.579$; $p < 0.001$; $\eta^2 = 0.753$; large). The post-hoc analysis showed higher FI values recorded after WU20 compared to WU10 ($p < 0.001$).

DISCUSSION

The aim of the present investigation was to compare the effect of WU10 and WU20 durations in a hot climate ($\sim 31^\circ\text{C}$), on thermal comfort, muscular power output and fatigue during specific repeated-sprint ability in soccer players. The main finding was that the WU10, compared to WU20, leads to a higher mean power output during the RSA test, but not peak power. The WU20 causes larger increases in RPE scores, in thermal discomfort sensation and the emergence of related signs of fatigue.

Power output and temperature

The present findings showed no difference between the effect of WU10 and WU20 on PP. However, higher MP was recorded after the WU10 compared to WU20. Thus, it seems that, in a hot climate, the two WU durations induced the same effect on the best RSA sprinting speed, usually occurring in the first or second trial [16]. This result seems to be in accordance with previous studies, showing that the environmental conditions (thermal neutral and hot) did not alter the effect of active WU on the first sprint power output, during the intermittent-sprint performance as passive WU did [32]. Others reported no effect of hot and humid conditions on short-term anaerobic exercise [18].

We observed a decline in power production starting from the 2nd trial and continuing to the last repetition in RSA, in both WU10 and WU20 sessions. Nonetheless, this decline was more remarkable following the WU20 compared to the WU10. The present findings

are in accordance with previous studies, suggesting reducing WU duration, and especially the RAISE stage in hot climate temperatures, for intermediate and intermittent efforts [3, 18]. Such WU reduction appears necessary to avoid an excessive increase in whole-body temperature and an impairment of repeated-sprinting performances [18]. Nonetheless, this reduction of WU duration should not concern the neural activation stage, being important for strength and power-based performances [33].

To the author's best knowledge, except the study of Yaicharoen et al. [32] aiming to assess the effect of active and passive WU (conducted in hot and moderate climate temperatures), on prolonged intermittent-sprint performance, no studies have investigated the effect of WU durations in hot climate on soccer repeated-sprint ability. Despite the current interest, oriented to investigate the effect of heat stress on different physical performances, the results are still inconclusive: Indeed, Mohr et al. [2], examining the physiological responses and physical performances during football in the heat, revealed that soccer peak sprinting speed improved in hot conditions. However, Morris et al. [20], examining soccer performances among female game players, concluded that sprint performances declined in hot compared to ambient temperatures. Drust et al. [18] obtained similar results, showing that power output during RSA was reduced in hot compared to ambient temperatures. The discrepancies between the aforementioned findings may be related to differences in participants' characteristics, their physical fitness level, or to differences in climate temperatures and/or relative humidity in the places where the studies were conducted.

The higher mean power output recorded after the WU10, in comparison to the WU20, indicates that the WU10 is a sufficient duration that allows the ergogenic effect of WU to be achieved, which seems to be in accordance with previous research suggesting that 8–10 min dynamic WU improved sprint performances in young soccer players [10, 11, 34]. Nonetheless, such comparison should be made with caution, as none of the aforementioned studies has mentioned the environment temperatures in which the experimental sessions were conducted.

An interesting observation in the present study was that temperature rises significantly after all WU durations, in accordance with the literature showing that core temperature rises rapidly within the first 3–5 min of moderate exercise and reaches a plateau after 10–20 min [14]. It was demonstrated that an increase in muscle temperature can be responsible for a 4% improvement of muscular leg power for each 1°C elevated [35]. Then, the similar power output in the first RSA trial and following both WU durations supports the importance of temperature-related effects on initial exercise repetition [6, 36] and highlights the reduced effect of non-temperature-related factors [32]. In addition, the increase in core temperature was shown to be the major factor responsible for improving the nerve conduction velocity, the enzymatic activities [37], the oxygen delivery to muscles and for decreasing muscular viscous resistance [38]. The present study findings showed a larger increase of T_{tym} after the

WU20 compared to the WU10 (0.7°C and 0.3°C, respectively), which seems to be in accordance with the results of Yaicharoen et al. [32] showing an elevation of temperature of ~0.3°C after 10 min active WU (55% $VO_{2\text{max}}$) in a hot climate (~35.8°C). Nonetheless, those changes are still inferior to the temperature variations reported by Drust et al. [18], recorded after an intermittent cycling effort (60% $VO_{2\text{max}}$) in a hot environment (~40°C), and estimated at ~1.1°C after 10 min; and ~1.5°C after 20 min of exercise. We can presume that the differences in temperature variations may be related to the differences in the used measuring methods (temperature pills [32], oesophageal temperature [18] vs tympanic temperature in the present study), or to the differences in environmental temperatures. While T_{tym} used in this investigation reflects more the peripheral rather than the central temperature, we can assume that the increase in T_{tym} is the result of metabolic heat production from active skeletal muscles' contractions responsible for heat production and changes in core temperature [3, 40]. Therefore, the decrease in power output after WU20 seems to be the result of an excessive elevation of core temperature and heat stress, which caused hyperthermia. It was reported that hyperthermia impairs high intensity sprinting [20], and repeated-sprinting ability [18], even though higher muscle temperatures are reached [39].

Fatigue index (FI), thermal comfort (TC) and rating of perceived exertion (RPE)

The present study findings revealed a higher fatigue index value after WU20 compared to WU10. To the author's best knowledge, this is the first study showing an effect of WU duration on fatigue index. Indeed previous studies demonstrated no effect of WU durations on fatigue index during the Wingate test [6–8], and reported that the effect of WU durations on FI was masked by its intrinsic variability. In the present study, the percentage of power decrease is related to the drop in power during the last five sprints during RSA. It was demonstrated that high-intensity exercise in the heat causes relevant impairment in oxygen delivery to the exercising muscles, related to cardiac and muscle blood flow decreases [40]. Taken together with the elevated RPE estimations and thermal discomfort recorded at the WU20 session, these observations suggest that fatigue has a complex origin and it is determined by an interplay between psychological and physiological factors. Therefore, future studies are required to better understand the mechanism by which hyperthermia causes central and peripheral fatigue in more challenging environmental conditions (extremal heat stress, elevated humidity, relative hypoxia).

CONCLUSIONS

The present study confirms that WU durations in a hot climate (~31°C) affect mean power output, thermal comfort and fatigue, but not peak power. The peak power output seems to be more affected by temperature-related, rather than non-temperature-related factors. The WU10 seems to be the most adequate to enhance lower limb

power output during a specific soccer repeated-sprint ability test, in hot climate. However, further increase of the preconditioning duration up to 20 min appears not to be useful as it induces a drop in muscular power output, thermal discomfort and fatigue. The current findings may assist coaches and soccer players when structuring the warm-up in a hot climate temperatures.

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Conflict of interest

The authors declare no conflict of interest.

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