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Title: Body temperature and physical performance responses are not maintained at the time of pitch-entry when typical substitute-specific match-day practices are adopted before simulated soccer match-play

Running head: Responses of soccer substitutes

1 **Abstract**

2 *Objectives:* To profile performance and physiological responses to typical patterns of match-day  
3 activity for second-half soccer substitutes.

4 *Design:* Descriptive

5 *Methods:* Following a warm-up, 13 male team sports players underwent ~85 min of rest, punctuated  
6 with five min rewarm-ups at ~25, ~50, and ~70 min, before ~30 min of simulated soccer match-play.  
7 Countermovement jump performance (jump height, peak power output), alongside 15 m sprints, were  
8 assessed post-warm-up, and pre- and post-simulated match-play. Core temperature, heart rate, ratings  
9 of perceived exertion, and blood glucose and lactate concentrations were measured throughout.

10 *Results:* Warm-up-induced core temperature elevations (~2.3%, +0.85°C; p<0.001) were maintained  
11 until after the first rewarm-up. Thereafter, core temperature was reduced from post-warm-up values  
12 until pre-simulated match-play (~1.6%, -0.60°C; p<0.001), where values were similar to pre-warm-up  
13 (37.07±0.24°C, p=0.981). Simulated match-play increased core temperature progressively (p≤0.05) but  
14 values remained lower than post-warm-up (~5 min; p=0.002) until ~10 min into exercise. From post-  
15 warm-up to pre-simulated match-play, sprint times (~3.9%, +0.10 s, p=0.003), jump height (~9.4%, -  
16 3.1 cm; p=0.017), and peak power output (~7.2%, -296 W; p<0.001) worsened. Despite increased  
17 ratings of perceived exertion and elevated blood lactate concentrations (p≤0.05), sprint times were  
18 maintained throughout exercise, whereas peak power increased (~7.8%, +294 W; p=0.006) pre- to post-  
19 exercise.

20 *Conclusions:* At the point of simulated pitch-entry, body temperature and physical performance  
21 responses were not maintained from warm-up cessation despite typical substitute-specific match-day  
22 practices being employed in thermoneutral conditions. Evidence of performance-limiting fatigue was  
23 absent during ~30 min of simulated match-play. These data question the efficacy of practices typically  
24 implemented by substitutes before pitch-entry.

25 **Key words:** Sprint, jump, warm-up, intermittent, rewarm-up, football

26 **Practical implications**

- 27
- In thermoneutral conditions, a rewarm-up protocol reflecting the typical match-day practices  
28 of soccer substitutes did not maintain body temperature or physical performance between  
29 warm-up cessation and simulated second-half pitch-entry.
  - To optimise physical performance upon match-introduction, practitioners should consider  
30 whether substitutes' existing pre-pitch-entry strategies are optimal.
  - Absence of substantial performance-limiting fatigue during ~30 min of simulated match-play  
31 highlights that bespoke post-match training and recovery strategies are warranted for  
32 substitutes.  
33  
34

## 35 **Introduction**

36 The introduction of substitutes represents one means by which soccer coaches or managers can attempt  
37 to positively influence match outcomes.<sup>1</sup> Whilst other motivations exist, strategic substitutions (i.e.,  
38 replacements that are not enforced due to injury) are often made with the primary aims of increasing  
39 the pace of play relative to players who started the match and/or changing team tactics, typically at half-  
40 time or later.<sup>1</sup> In addition to appropriate pre-exercise strategies potentially helping to reduce injury-  
41 risk,<sup>2</sup> such objectives mean that substitutes should preferably enter the pitch having prepared in a way  
42 that facilitates high-intensity physical performance immediately upon match introduction.<sup>1</sup>

43 An active pre-match warm-up can help members of the starting team smooth the transition from rest to  
44 exercise, thus improving physical performance capacity and potentially reducing injury-risk during the  
45 opening stages of match-play.<sup>3, 4</sup> For team sports players, acknowledging the role of other metabolic  
46 (e.g., speeding of oxygen uptake kinetics), neural (e.g., postactivation potentiation), and psychological  
47 (e.g., establishing task-focus) mechanisms,<sup>4-6</sup> the prominent ergogenic effects of warming-up may be  
48 derived primarily from elevated muscle ( $T_m$ ) and core ( $T_{core}$ ) temperatures.<sup>3-5</sup> Increased body  
49 temperature demonstrates a positive relationship with improved high-intensity exercise performance,  
50 with a 1°C change in  $T_m$  augmenting muscular power output by ~2-10%.<sup>4, 7</sup>

51 Substitutes typically perform active warm-ups prior to the match kick-off, either independently or  
52 alongside members of the starting team.<sup>1, 8, 9</sup> However, unless additional ergogenic strategies are  
53 employed, the length of time that typically separates the end of the pre-match warm-up and a substitute's  
54 entry onto the pitch (i.e., often  $\geq 85$  min) may elicit physiological responses (e.g., decreased body  
55 temperature) that negatively affect physical performance capacity and elevate injury-risk immediately  
56 upon match-introduction.<sup>10-12</sup> Partly due to practical and regulatory restrictions,<sup>1</sup> published and  
57 empirical observations suggest that awaiting substitutes often perform minimal activity between the  
58 match kick-off and pitch-entry.<sup>1, 8, 9</sup> Indeed, professional substitutes performed ~3 rewarm-up  
59 bouts·player<sup>-1</sup>·match<sup>-1</sup>, each lasting ~3-6 min and eliciting substantially lower absolute demands  
60 compared with the substitute-specific pre-match warm-up.<sup>8</sup> Despite practitioners acknowledging the  
61 importance of appropriate pre-pitch-entry preparations for allowing substitutes to positively influence

62 a match,<sup>1</sup> the efficacy of current practices remains unknown. Moreover, whilst substitutes have  
63 demonstrated transient post-pitch-entry changes in physical performance indicators such as total and/or  
64 high-speed running distance,<sup>8, 9</sup> the acute physiological responses following second-half match  
65 introduction are unclear. Therefore, this study profiled the physiological and performance responses to  
66 typical substitute-specific pre-pitch-entry preparations, while assessing the effects of simulated partial  
67 match-play.

68

## 69 **Methods**

70 Following receipt of ethical approval, 13 male recreational team sports athletes (age:  $24\pm 7$  years, mass:  
71  $79.5\pm 10.3$  kg, stature:  $1.80\pm 0.04$  m) volunteered to participate. All participants provided written consent  
72 before data collection, whilst preliminary visits allowed familiarisation with all procedures.  
73 Retrospective power calculations (G\*Power v3.1.9.2; Universität Düsseldorf, Germany) highlighted  
74 that  $>90\%$  statistical power existed for differences in physiological and performance variables.

75 Players attended an indoor sports hall (temperature:  $16.1\pm 1.9$  °C, humidity:  $55\pm 4\%$ ) following an  
76 overnight fast, having refrained from caffeine, alcohol, and strenuous exercise during the preceding 24  
77 h. Mid-flow urine samples were taken before participants consumed a standardised breakfast (Rice  
78 Krispies; Kellogg's, UK, and semi skimmed milk: 1067 KJ, 44 g carbohydrates, 10 g protein, 4 g fat)  
79 with 500 ml of water (Highland Spring; Highland Spring Group, UK). Body mass was measured before  
80  $\sim 45$  min of rest preceded a standardised warm-up ( $\sim 20$  min) consisting of dynamic stretches and  
81 movements progressing from low- to moderate-intensity, concluding with sprints at near-maximal  
82 speeds. Five min of passive rest followed, during which water (500 ml) was consumed.

83 Isolated performance testing was conducted post-warm-up (within five min), before an  $\sim 85$  min  
84 transition period. This time was mostly spent seated, wearing normal training attire and viewing  
85 standardised footage of soccer match-play on a mobile tablet device (iPad, Apple, USA), but was  
86 punctuated at  $\sim 25$  min (RWU1),  $\sim 50$  min (half-time RWU), and  $\sim 70$  min (RWU2), by  $\sim 5.3$  min of  
87 rewarm-up activity.<sup>8, 9, 13</sup> Rewarm-ups were performed within a narrow space that reflected a typical

88 pitch side-line area, and included dynamic stretches alongside low- to moderate-intensity movements.<sup>8</sup>

89 <sup>9</sup> Further performance testing (i.e., pre-SMS) took place ~10 min after RWU2, before ~30 min of the  
90 soccer match simulation (SMS<sup>14</sup>) requiring participants to perform five ~4.5 min ‘blocks’ of exercise  
91 (i.e., block one to block five) separated by two min passive rest.

92 Sprint time (15 m) was repeatedly assessed as part of the SMS, whereas isolated 15 m sprint times and  
93 countermovement jump (CMJ) performances were tested post-warm-up, immediately pre-SMS, and  
94 post-SMS. Each CMJ commenced in a standing position, from which participants performed a  
95 preparatory ‘dip’ before explosively jumping to attain maximum height. Hands remained on hips  
96 throughout. A portable force platform (FP4060-05-PT; 1000 Hz, Bertec Corporation, USA) provided  
97 vertical force-time data, from which peak power (PP) output and jump height (JH) were calculated.<sup>15, 16</sup>

98 For sprint assessments, participants sprinted as fast as possible from a static start through markers placed  
99 20 m away, with timing gates (Brower TC-System; Brower Timing Systems, USA) at 0 m and 15 m.

100 An ingestible sensor (CorTemp™; HQ Inc, USA) allowed  $T_{\text{core}}$  to be assessed pre- and post-warm-up,  
101 before and after each rewarm-up, pre-SMS, and after every ~4.5 min block of the SMS. This method is  
102 safe, valid, and reliable<sup>17</sup> and, as per the manufacturer’s guidelines, sensors were consumed at least  
103 three hours before the first measurement. Capillary blood samples, analysed for glucose and lactate  
104 concentrations (YSI 2300 STAT PLUS; Yellow Springs Instruments, USA), were taken pre- and post-  
105 warm-up, before each rewarm-up, pre-SMS, and after ~15 min and ~30 min of simulated match-play.

106 Heart rate was continuously recorded during exercise (Polar T31; Polar Electro, Finland), whilst  
107 participants indicated subjective ratings of perceived exertion (RPE; 6-20)<sup>18</sup> for the warm-up, each  
108 rewarm-up, and every block of the SMS. Pre- to post-trial changes in urine osmolality (Osmocheck;  
109 Vitech Scientific, UK) and fluid-corrected body mass were determined.

110 Statistical analyses were conducted using SPSS (Version 21.0; SPSS Inc., USA), with significance  
111 established when  $p \leq 0.05$ . One-way repeated measures analyses of variance were used to assess whether  
112 ‘time’ influenced physiological and performance responses. Mauchly’s test was consulted, and the  
113 Greenhouse-Geisser correction applied if the assumption of sphericity was violated. Significant time  
114 effects were investigated via post-hoc Bonferroni-adjusted pairwise comparisons, whilst changes in

115 body mass and urine osmolality were assessed using paired t-tests. Cohen's d effect sizes (ES) were  
116 calculated for post-hoc comparisons where  $p \leq 0.05$ , and were interpreted as: 0.00-0.19, *trivial*; 0.20-  
117 0.59, *small*; 0.60-1.20, *moderate*; 1.21-2.0, *large*; and  $>2.01$ , *very large* effects.<sup>19</sup> Where necessary,  
118 mean data from the corresponding time-point was imputed for any missing values.<sup>20</sup>

119

## 120 **Results**

121 Time influenced  $T_{\text{core}}$  ( $F_{(4,43)}=153.022$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2=0.927$ ), which was elevated by the warm-  
122 up ( $p \leq 0.001$ , ES: 2.27,  $37.7 \pm 0.3^\circ\text{C}$ ) and maintained at pre-RWU1 ( $37.3 \pm 0.3^\circ\text{C}$ ) and post-RWU1  
123 ( $37.3 \pm 0.3^\circ\text{C}$ ). Relative to post-warm-up,  $T_{\text{core}}$  had declined by the pre-half-time RWU timepoint ( $p$   
124  $=0.005$ , ES: 1.71,  $37.2 \pm 0.3^\circ\text{C}$ ) and remained lower than post-warm-up values thereafter (all  $p \leq 0.05$ ,  
125 ES: 1.37-2.40), returning to pre-warm-up levels at pre-RWU2, post-RWU2, and pre-SMS ( $37.0$ - $37.1^\circ\text{C}$ ;  
126 Figure 1). Two blocks of simulated match-play (~10 min) were necessary to restore  $T_{\text{core}}$  to at least post-  
127 warm-up values ( $37.8 \pm 0.3^\circ\text{C}$ ). Elevated  $T_{\text{core}}$  was observed after block one of simulated match-play  
128 compared with pre-SMS ( $p = 0.002$ , ES: 0.86,  $37.3 \pm 0.3^\circ\text{C}$ ), before further stepwise increases between  
129 each subsequent SMS block (all  $p \leq 0.05$ , ES: 0.64-1.72). From block three onwards ( $\geq 38.2^\circ\text{C}$ ),  $T_{\text{core}}$   
130 exceeded all pre-exercise values (all  $p \leq 0.05$ , ES: 1.55-7.06).

131

132 \*\*\*\*INSERT FIGURE 1 HERE\*\*\*\*

133

134 Time also influenced isolated 15 m sprint times ( $F_{(2,24)}=6.275$ ,  $p = 0.006$ ,  $\text{partial-}\eta^2 = 0.343$ ), as well  
135 as CMJ PP ( $F_{(2,24)}=14.389$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2 = 0.545$ ) and JH ( $F_{(2,24)}=5.92$ ,  $p = 0.008$ ,  $\text{partial-}\eta^2$   
136  $=0.33$ ). Isolated sprints performed pre-SMS ( $2.54 \pm 0.12$  s,  $p = 0.003$ , ES: 0.77) were slower than those  
137 performed post-warm-up ( $2.44 \pm 0.13$  s), whereas post-SMS times ( $2.51 \pm 0.10$  s) remained unchanged  
138 from pre-SMS values. Post-warm-up CMJ responses (PP:  $4088 \pm 884$  W, JH:  $32.7 \pm 5.7$  cm) exceeded  
139 pre-SMS values (PP:  $3792 \pm 873$  W, JH:  $29.6 \pm 4.8$  cm) for both PP ( $p \leq 0.001$ , ES: 0.34) and JH ( $p = 0.017$ ,



140 ES: 0.58). Increased PP ( $p = 0.006$ , ES: 0.33) was observed from pre-SMS to post-SMS ( $4086 \pm 913$  W),  
141 whereas sprint performances remained unchanged throughout exercise.

142

143 \*\*\*\*INSERT TABLE 1 HERE\*\*\*\*

144

145 For mean ( $F_{(3,32)} = 602.057$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2 = 0.980$ ) and peak ( $F_{(4,46)} = 216.234$ ,  $p \leq 0.001$ ,  $\text{partial-}$   
146  $\eta^2 = 0.947$ ) HR (Table 1), warm-up (all  $p \leq 0.001$ , ES: 2.72-5.44) and all SMS (all  $p \leq 0.001$ , ES: 5.20-  
147 10.20) responses exceeded all rewarm-up values, whilst mean HR was also greater for each SMS block  
148 compared with the warm-up (all  $p \leq 0.001$ , ES: 2.76-4.66). Mean HR increased from SMS blocks one  
149 to two ( $p \leq 0.001$ , ES: 1.78) and two to three ( $p \leq 0.001$ , ES: 0.84), before stabilising thereafter. For RPE  
150 ( $F_{(2,30)} = 192.254$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2 = 0.941$ ), Table 1 shows that warm-up RPE exceeded values for  
151 each rewarm-up ( $p \leq 0.001$ , ES: 1.97-2.11), and all SMS blocks elicited higher values than both the  
152 warm-up and rewarm-ups ( $p \leq 0.05$ , ES: 1.42-8.11). Moreover, RPE was similar after SMS blocks one  
153 and two, before increasing from blocks two to three ( $p \leq 0.001$ , ES: 0.66), and blocks three to four ( $p$   
154  $= 0.032$ , ES: 0.56).

155 Blood lactate concentrations ( $F_{(1,16)} = 76.953$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2 = 0.881$ ) were elevated at post-warm-  
156 up (all  $p \leq 0.001$ , ES: 1.48-2.52,  $2.0 \pm 0.7$  mmol $\cdot$ l $^{-1}$ ) and after  $\sim 15$  min ( $5.5 \pm 1.6$  mmol $\cdot$ l $^{-1}$ ) and  $\sim 30$  min  
157 ( $5.3 \pm 1.9$  mmol $\cdot$ l $^{-1}$ ) of simulated match-play (all  $p \leq 0.001$ , ES: 3.02-4.30), compared with all other time-  
158 points (Figure 2A). Although blood lactate concentrations were similar following  $\sim 15$  min and  $\sim 30$  min  
159 of exercise, concentrations exceeded post-warm-up values (both  $p \leq 0.05$ , ES: 2.26-2.83). For blood  
160 glucose ( $F_{(2,30)} = 8.944$ ,  $p \leq 0.001$ ,  $\text{partial-}\eta^2 = 0.427$ ), concentrations at pre-RWU1 ( $p = 0.024$ , ES: 1.35,  
161  $4.2 \pm 0.9$  mmol $\cdot$ l $^{-1}$ ), and after  $\sim 15$  min ( $p = 0.009$ , ES: 1.79,  $4.9 \pm 1.2$  mmol $\cdot$ l $^{-1}$ ) and  $\sim 30$  min ( $p = 0.015$ ,  
162 ES: 1.70,  $5.2 \pm 1.5$  mmol $\cdot$ l $^{-1}$ ) of simulated match-play, exceeded post-warm-up values ( $3.3 \pm 0.4$  mmol $\cdot$ l $^{-1}$ ;  
163 Figure 2B). When corrected for fluid intake and losses, body mass declined ( $t_{(12)} = 3.91$ ,  $p = 0.002$ , ES:  
164 0.07) from pre-warm-up ( $79.5 \pm 10.7$  kg) to post-SMS ( $78.8 \pm 10.7$  kg), whereas urine osmolality at post-

165 SMS ( $207 \pm 153 \text{ mOsm} \cdot \text{kg}^{-1}$ ) had decreased ( $t_{(12)} = 5.175$ ,  $p \leq 0.001$ , ES: 2.2) from pre-warm-up ( $657 \pm 259$   
166  $\text{mOsm} \cdot \text{kg}^{-1}$ ).

167

168 \*\*\*\*INSERT FIGURE 2 HERE\*\*\*\*

169

## 170 **Discussion**

171 This study examined the physiological and performance responses to practices that replicated the typical  
172 match-day activities of professional soccer substitutes. Despite rewarm-ups, warm-up-induced  
173 elevations in  $T_{\text{core}}$  were not maintained at the time of pitch-entry. Alongside  $\sim 1.6\%$  lower  $T_{\text{core}}$  values,  
174 CMJ ( $\sim 7.2\text{-}9.4\%$ ) and 15 m sprint ( $\sim 3.9\%$ ) performances also reduced when assessed pre-SMS versus  
175 post-warm-up. Whilst simulated match-play elicited progressive increases,  $T_{\text{core}}$  did not reach post-  
176 warm-up values until  $\sim 10$  min into exercise. Sprint times remained unchanged throughout  $\sim 30$  min of  
177 simulated match-play and CMJ PP increased as a function of exercise. These novel findings question  
178 the efficacy of current practice and may benefit practitioners seeking to optimise the acute pre-pitch-  
179 entry preparatory strategies of substitutes. Likewise, insight into post-pitch-entry responses could help  
180 to inform tailored training and recovery protocols for this bespoke population of soccer players.

181 Whilst  $T_{\text{core}}$  was elevated by the initial warm-up, this response had dissipated well in advance of the  
182 simulated second-half pitch-entry. Several investigations highlight rapid declines in body temperature  
183 when periods of inactivity follow exercise;<sup>6, 12, 21</sup> responses that are typically accompanied by decreases  
184 in physical performance capacity and potential elevation of injury-risk factors (e.g., reduced dynamic  
185 eccentric hamstring strength).<sup>6, 12, 21</sup> Contrary to studies reporting reductions within  $\sim 10\text{-}15$  min of  
186 exercise cessation,<sup>6, 21</sup>  $T_{\text{core}}$  was maintained relative to post-warm-up values until the start of half-time  
187 ( $\sim 50$  min). Where  $\geq 15$  min separates the end of the pre-match warm-up and a player's introduction into  
188 a match, performing short bouts of rewarm-up activity may help to preserve body temperature and  
189 attenuate declines in explosive physical performance compared with passive rest.<sup>3</sup> Although values did  
190 not increase significantly from pre-RWU1 to post-RWU1, it is possible that RWU1 may have helped

191 to slow the rate at which  $T_{\text{core}}$  declined following warm-up cessation. Notwithstanding,  $T_{\text{core}}$  declined  
192 from post-warm-up and had returned to pre-warm-up levels prior to simulated pitch-entry, whilst CMJ  
193 and 15 m sprint performances worsened during this time. Acknowledging that rewarm-up practices may  
194 vary,<sup>1</sup> replicating the pattern of activities performed by professional soccer substitutes<sup>8</sup> did not maintain  
195  $T_{\text{core}}$  and physical performance responses from post-warm-up values until the time of pitch-entry in  
196 thermoneutral conditions. Such findings suggest that modifying the pre-pitch-entry activities currently  
197 adopted by substitute players warrants further investigation.

198 Rewarm-ups lasted approximately five min and consisted of dynamic stretching alongside low- to  
199 moderate-intensity movements such as jogging and side-stepping. Although such practices reflect  
200 observations from professional soccer players,<sup>8</sup> warm-up and rewarm-up intensity may modulate  
201 physical performance during subsequent exercise.<sup>3, 22, 23</sup> Notably, 800 m running performance was  
202 enhanced by ~1% when preceded by combined striding and race-pace running, compared with an  
203 equidistant bout of striding alone.<sup>23</sup> Moreover, achieving ~90% of an individual's maximum HR during  
204 prior exercise can benefit subsequent performance during explosive tasks such as jumps and sprints.<sup>3</sup>  
205 Although HR during the warm-up peaked at >90% of maximum HR, mean and peak HR during rewarm-  
206 ups were ~26-31 beats·min<sup>-1</sup> and ~48-50 beats·min<sup>-1</sup> lower, respectively. Speculatively, as RPE values  
207 were also lower for rewarm-ups, increasing rewarm-up intensity while remaining within tolerable limits  
208 could elicit favourable physiological responses (e.g., improved body temperature maintenance,  
209 postactivation potentiation), that attenuate the reductions in physical performance observed presently  
210 between warm-up cessation and pitch-entry. Acknowledging the potential for detrimental effects in hot  
211 or humid conditions (e.g., temperatures  $\geq 25$  °C, humidity  $\geq 60\%$ ),<sup>24</sup> combining appropriate rewarm-up  
212 activity with passive heat maintenance techniques (e.g., wearing heated or insulated garments) may  
213 provide additional performance benefits in cold or thermoneutral environments compared with active  
214 rewarm-ups alone.<sup>21</sup>

215 Rewarm-up strategies reflected the fact that practical and regulatory barriers may modulate the activities  
216 that substitutes can perform between kick-off and pitch-entry.<sup>1</sup> The design of modern stadia often limits  
217 the space that is available for rewarm-ups, which could partly explain observations that professional

218 substitutes covered  $<2 \text{ m}\cdot\text{min}^{-1}$  at  $>5.5 \text{ m}\cdot\text{s}^{-1}$  during each bout of pre-pitch-entry activity and did not  
219 exceed  $7 \text{ m}\cdot\text{s}^{-1}$  at any time prior to match introduction.<sup>8</sup> Although theoretical, practitioners have  
220 postulated that providing more space within which to perform rewarm-ups may facilitate improvements  
221 in pre-pitch-entry preparations that could translate favourably into enhanced physical performance  
222 and/or reduced injury-risk thereafter.<sup>1</sup> Moreover, regulations in many competitions require team  
223 officials to remain within a designated technical area whilst match-play is underway.<sup>25</sup> Acknowledging  
224 that different teams provide substitutes with varying levels of guidance in relation to pre-pitch-entry  
225 strategies,<sup>1</sup> the content of any rewarm-up activity must ultimately be determined by the players  
226 themselves. Being named as a substitute has been associated with reduced motivation to prepare,<sup>13, 26</sup>  
227 whilst empirical observations highlight how events unfolding in the match appear to affect the self-  
228 selected activities performed by players awaiting pitch-entry.<sup>8</sup> As superior outcomes have been realised  
229 following coach-supervised compared with unsupervised training,<sup>27</sup> allowing members of team staff to  
230 accompany substitutes during rewarm-ups may enable more varied and better structured pre-pitch-entry  
231 preparations compared with when exclusively player-led activities are performed.<sup>1</sup>

232 Despite elevated blood lactate concentrations and progressive increases in RPE, sprint times were not  
233 reduced throughout  $\sim 30$  min of simulated match-play. Acknowledging that adherence to audio signals  
234 to control exercise tempo precluded the adoption of self-pacing strategies in the present study, these  
235 observations conflict with match-play data whereby professional substitutes have demonstrated  
236 transient changes in physical outputs following pitch-entry.<sup>8, 28</sup> Bradley et al.<sup>28</sup> reported a tendency for  
237 total and high-speed running distances covered by substitutes to increase as the second-half progressed,  
238 whereas defining five min epochs relative to the moment of a player's introduction into a match (i.e.,  
239 rather than relative to the match kick-off) highlighted up to  $\sim 39\%$  reductions in physical outputs  
240 between the first and second post-pitch-entry epoch, before a plateau.<sup>8</sup> Speculatively, given that the  
241 current study highlights  $T_{\text{core}}$  declines from post-warm-up to pre-SMS, and that  $\sim 10$  min of simulated  
242 match-play was required to restore  $T_{\text{core}}$  to post-warm-up values, it is possible that the observed match-  
243 play responses could reflect a pacing strategy that partly influenced by efforts to 'warm-up' having  
244 already entered the pitch. As a substitute's perceived ability to provide an immediate and sustained

245 physical impact on a match is highly valued by soccer coaches and managers,<sup>1</sup> it is notable that  
246 increasing the amount of pre-pitch-entry activity performed by professional substitutes appeared to  
247 benefit initial physical outputs and reduce the magnitude of decline after match-introduction.<sup>9</sup>

248 In addition to a potential ergogenic temperature-raising effect, maintenance of CMJ JH and sprint  
249 performance alongside ~7.8% improvements in CMJ PP from pre-SMS to post-SMS suggest the  
250 absence of substantial acute fatigue during ~30 min of simulated match-play. Acknowledging that  
251 responses may differ according to the timing of a player's introduction into a match, these observations  
252 support the notion that substitutes may benefit from bespoke post-match training and recovery practices  
253 compared with whole-match players.<sup>1</sup> Notably, it may be important for partial-match players to  
254 undertake 'top-up' conditioning to maintain appropriate physical loading patterns that promote  
255 favourable adaptations and minimise injury-risk throughout a season.<sup>1,29</sup> Moreover, whilst  $\leq 45$  min of  
256 match-play is unlikely to reduce fibre-specific muscle glycogen concentrations to the extent of 90+ min  
257 of soccer-specific exercise,<sup>30</sup> practical considerations associated with the uncertainty surrounding team  
258 selection and/or the likely extent of their upcoming match-play exposure often requires substitutes to  
259 adopt the same high-carbohydrate pre-match fuelling strategies as members of the starting team.<sup>1</sup>  
260 Achieving desired energy balance may therefore require substitute-specific post-match nutritional  
261 strategies that account for likely reductions in energy and/or carbohydrate utilisation for second-half  
262 substitutes relative to whole-match players.

263

## 264 **Conclusion**

265 Despite three rewarm-ups being performed in thermoneutral conditions,  $T_{\text{core}}$  was not maintained from  
266 post-warm-up at the point of simulated second-half pitch entry and 15 m sprint (~3.9%) and CMJ (~7.2-  
267 9.4%) performances reduced during this time. Thereafter, progressive increases in  $T_{\text{core}}$  alongside  
268 performance maintenance or improvement during ~30 min of simulated match-play suggests an absence  
269 of performance-limiting fatigue and possible warming-up effects throughout exercise.

270

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341

342

343 **Legends**

344 **Table 1:** Physiological and performance responses during a simulated match-day for substitutes.

345 AU: Arbitrary units, HR: Heart rate, RPE: Rating of perceived exertion, RWU: Rewarm-up, SMS:  
346 Soccer match simulation, <sup>a</sup>: different from the initial warm-up, <sup>b</sup>: different from RWU1, <sup>c</sup>: Different  
347 from half-time RWU, <sup>d</sup>: Different from RWU2, <sup>e</sup>: Different from SMS block 1, <sup>f</sup>: Different from SMS  
348 block 2, <sup>g</sup>: Different from SMS block 3, <sup>h</sup>: Different from SMS block 4, <sup>i</sup>: Different from SMS block  
349 5. A single letter denotes differences at the  $p \leq 0.05$  level, whilst  $p \leq 0.001$  is represented by two of the  
350 same letter. Data are presented as mean  $\pm$  standard deviation.

351

352 **Figure 1:** Time-course of changes in core temperature during a simulated match-day for substitutes  
353 (n=13).

354 RWU: Rewarm-up, SMS: Soccer match simulation, <sup>a</sup>: Different from pre-warm-up, <sup>b</sup>: Different from  
355 post-warm-up, <sup>c</sup>: Different from pre-RWU1, <sup>d</sup>: Different from post-RWU1, <sup>e</sup>: Different from pre-half-  
356 time RWU, <sup>f</sup>: Different from post-half-time RWU, <sup>g</sup>: Different from pre-RWU2, <sup>h</sup>: Different from  
357 post-RWU2, <sup>i</sup>: Different from pre-SMS, <sup>j</sup>: Different from block 1, <sup>k</sup>: Different from block 2, <sup>l</sup>:  
358 Different from block 3, <sup>m</sup>: Different from block 4, <sup>n</sup>: Different from block 5. A single letter denotes  
359 differences at the  $p \leq 0.05$  level, whilst  $p \leq 0.001$  is represented by two of the same letter. Data are  
360 presented as mean  $\pm$  standard deviation.

361

362 **Figure 2:** Time-course of changes in blood lactate (panel A) and blood glucose (panel B)  
363 concentrations during a simulated match-day for substitutes (n=13).

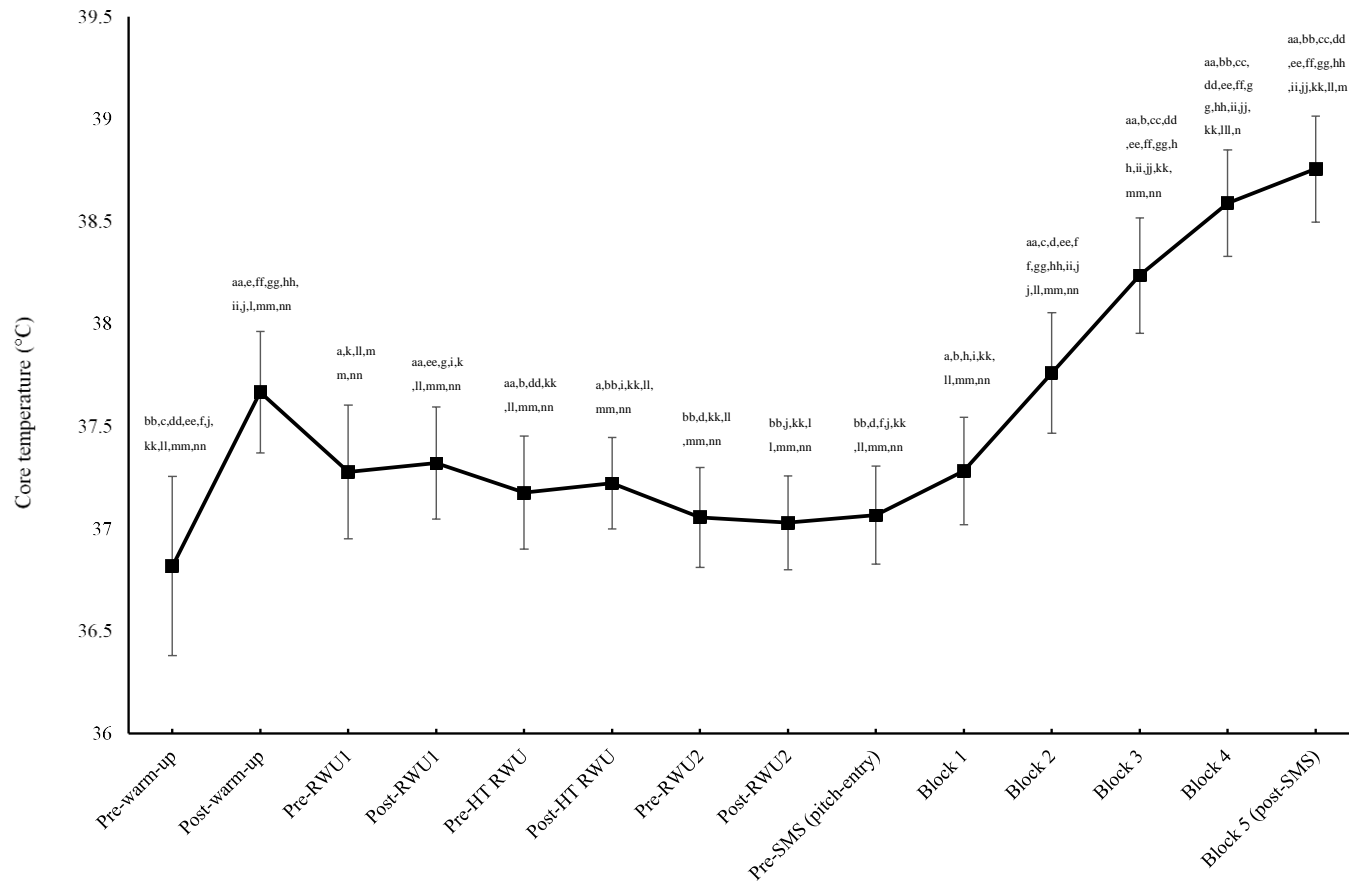
364 RWU: Rewarm-up, SMS: Soccer match simulation, <sup>a</sup>: Different from pre-warm-up, <sup>b</sup>: Different from  
365 post-warm-up, <sup>c</sup>: Different from pre-RWU1, <sup>d</sup>: Different from pre-half-time RWU, <sup>e</sup>: Different from  
366 pre-RWU2, <sup>f</sup>: Different from pre-SMS, <sup>g</sup>: Different from block 3, <sup>h</sup>: Different from block 5. A single  
367 letter denotes differences at the  $p \leq 0.05$  level, whilst  $p \leq 0.001$  is represented by two of the same letter.  
368 Data are presented as mean  $\pm$  standard deviation.



**Table 1:** Physiological and performance responses during a simulated match-day for substitutes (n = 13).

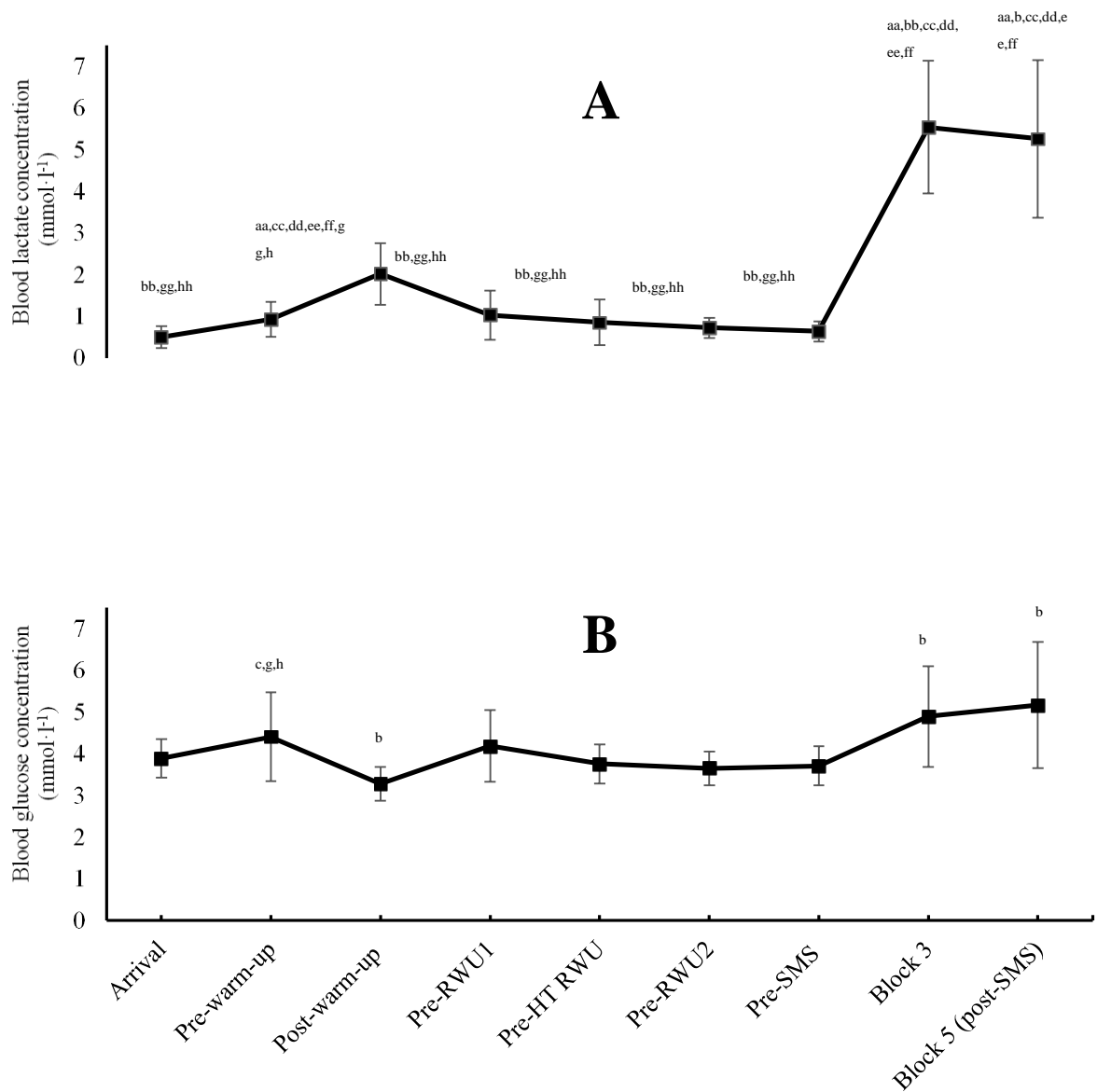
Variable	Warm-up	RWU1	Half-time RWU	RWU2	SMS block 1	SMS block 2	SMS block 3	SMS block 4	SMS block 5
<b>RPE (AU)</b>	11 ± 2 bb,cc,dd,e,ff,gg,hh,ii	7 ± 1 aa,ee,ff,gg,hh,ii	7 ± 1 aa,ee,ff,gg,hh,ii	7 ± 1 aa,ee,ff,gg,hh,ii	14 ± 2 a,bb,cc,dd,g,hh,ii	15 ± 2 aa,bb,cc,dd,gg,hh,i i	16 ± 2 aa,bb,cc,dd,e,ff,h,i	17 ± 2 aa,bb,cc,dd,ee,ff,g g	18 ± 1 aa,bb,cc,dd,ee,ff,g
<b>Mean HR (beats·min<sup>-1</sup>)</b>	139 ± 10 bb,cc,dd,ee,ff,gg,hh,i i	113 ± 8 aa,dd,ee,ff,gg,hh,ii	111 ± 10 aa,ee,ff,gg,hh,ii	108 ± 8 aa,bb,ee,ff,gg,hh,ii	161 ± 5 aa,bb,cc,dd,ff,gg,h h,ii	171 ± 6 aa,bb,cc,dd,ee,gg, h,i	175 ± 5 aa,bb,cc,dd,ee,ff	175 ± 5 aa,bb,cc,dd,ee,f	176 ± 5 aa,bb,cc,dd,ee,f
<b>Peak HR (beats·min<sup>-1</sup>)</b>	188 ± 9 <sup>bb,cc,dd</sup>	140 ± 9 aa,ee,ff,gg,hh,ii	138 ± 9 aa,ee,ff,gg,hh,ii	138 ± 10 aa,ee,ff,gg,hh,ii	189 ± 10 bb,cc,dd,g	192 ± 6 bb,cc,dd,g	196 ± 6 bb,cc,dd,gg,f	192 ± 4 bb,cc,dd	191 ± 3 bb,cc,dd
<b>Mean HR (%<sub>max</sub>)</b>	69 ± 6 bb,cc,dd,ee,ff,gg,hh,i i	57 ± 4 aa,dd,ee,ff,gg,hh,ii	55 ± 5 aa,ee,ff,gg,hh,ii	54 ± 4 aa,bb,ee,ff,gg,hh,ii	81 ± 3 aa,bb,cc,dd,ff,gg,h h,ii	85 ± 4 aa,bb,cc,dd,ee,gg, h,i	88 ± 4 aa,bb,cc,dd,ee,ff	88 ± 5 aa,bb,cc,dd,ee,f	88 ± 5 aa,bb,cc,dd,ee,f
<b>Peak HR (%<sub>max</sub>)</b>	94 ± 6 <sup>bb,cc,dd</sup>	70 ± 5 aa,ee,ff,gg,hh,ii	69 ± 4 aa,ee,ff,gg,hh,ii	69 ± 5 aa,ee,ff,gg,hh,ii	95 ± 5 bb,cc,dd,g	97 ± 4 bb,cc,dd,g	98 ± 4 bb,cc,dd,gg,f	96 ± 3 bb,cc,dd	96 ± 3 bb,cc,dd
<b>15 m SMS sprint time (s)</b>	Not applicable	Not applicable	Not applicable	Not applicable	2.76 ± 0.16	2.80 ± 0.22	2.84 ± 0.23	2.95 ± 0.30	2.84 ± 0.31

AU: Arbitrary units, HR: Heart rate, RPE: Rating of perceived exertion, RWU: Rewarm-up, SMS: Soccer match simulation, <sup>a</sup>: different from the warm-up, <sup>b</sup>: different from RWU1, <sup>c</sup>: Different from half-time RWU, <sup>d</sup>: Different from RWU2, <sup>e</sup>: Different from SMS block 1, <sup>f</sup>: Different from SMS block 2, <sup>g</sup>: Different from SMS block 3, <sup>h</sup>: Different from SMS block 4, <sup>i</sup>: Different from SMS block 5. A single letter denotes differences at the p ≤ 0.05 level, whilst p ≤ 0.001 is represented by two of the same letter. Data are presented as mean ± standard deviation.



369 **Figure 1:** Time-course of changes in core temperature during a simulated match-day for substitutes (n=13).

370 RWU: Rewarm-up, SMS: Soccer match simulation, <sup>a</sup>: Different from pre-warm-up, <sup>b</sup>: Different from post-warm-up, <sup>c</sup>: Different from pre-RWU1, <sup>d</sup>: Different  
 371 from post-RWU1, <sup>e</sup>: Different from pre-half-time RWU, <sup>f</sup>: Different from post-half-time RWU, <sup>g</sup>: Different from pre-RWU2, <sup>h</sup>: Different from post-RWU2, <sup>i</sup>:  
 372 Different from pre-SMS, <sup>j</sup>: Different from block 1, <sup>k</sup>: Different from block 2, <sup>l</sup>: Different from block 3, <sup>m</sup>: Different from block 4, <sup>n</sup>: Different from block 5. A  
 373 single letter denotes differences at the  $p \leq 0.05$  level, whilst  $p \leq 0.001$  is represented by two of the same letter. Data are presented as mean  $\pm$  standard deviation.



374

375 **Figure 2:** Time-course of changes in blood lactate (panel A) and blood glucose (panel B)  
 376 concentrations during a simulated match-day for substitutes (n=13).

377 RWU: Rewarm-up, SMS: Soccer match simulation, <sup>a</sup>: Different from pre-warm-up, <sup>b</sup>: Different from  
 378 post-warm-up, <sup>c</sup>: Different from pre-RWU1, <sup>d</sup>: Different from pre-half-time RWU, <sup>e</sup>: Different from  
 379 pre-RWU2, <sup>f</sup>: Different from pre-SMS, <sup>g</sup>: Different from block 3, <sup>h</sup>: Different from block 5. A single  
 380 letter denotes differences at the  $p \leq 0.05$  level, whilst  $p \leq 0.001$  is represented by two of the same letter.  
 381 Data are presented as mean  $\pm$  standard deviation.

382