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

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Abstract

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

Design: Descriptive

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

Results: Warm-up-induced core temperature elevations (~2.3%, +0.85°C; $p<0.001$) were maintained until after the first rewarm-up. Thereafter, core temperature was reduced from post-warm-up values until pre-simulated match-play (~1.6%, -0.60°C; $p<0.001$), where values were similar to pre-warm-up (37.07±0.24°C, $p=0.981$). Simulated match-play increased core temperature progressively ($p\leq0.05$) but values remained lower than post-warm-up (~5 min; $p=0.002$) until ~10 min into exercise. From post-warm-up to pre-simulated match-play, sprint times (~3.9%, +0.10 s, $p=0.003$), jump height (~9.4%, -3.1 cm; $p=0.017$), and peak power output (~7.2%, -296 W; $p<0.001$) worsened. Despite increased ratings of perceived exertion and elevated blood lactate concentrations ($p\leq0.05$), sprint times were maintained throughout exercise, whereas peak power increased (~7.8%, +294 W; $p=0.006$) pre- to post-exercise.

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

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

Practical implications

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

Introduction

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

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

Substitutes typically perform active warm-ups prior to the match kick-off, either independently or alongside members of the starting team.[1, 8, 9] However, unless additional ergogenic strategies are employed, the length of time that typically separates the end of the pre-match warm-up and a substitute's entry onto the pitch (i.e., often ≥85 min) may elicit physiological responses (e.g., decreased body temperature) that negatively affect physical performance capacity and elevate injury-risk immediately upon match-introduction.[10-12] Partly due to practical and regulatory restrictions,[1] published and empirical observations suggest that awaiting substitutes often perform minimal activity between the match kick-off and pitch-entry.[1, 8, 9] Indeed, professional substitutes performed ~3 rewarm-up bouts·player^{-1}·match^{-1}, each lasting ~3-6 min and eliciting substantially lower absolute demands compared with the substitute-specific pre-match warm-up.[8] Despite practitioners acknowledging the importance of appropriate pre-pitch-entry preparations for allowing substitutes to positively influence a match,[1] the efficacy of current practices remains unknown. Moreover, whilst substitutes have demonstrated transient post-pitch-entry changes in physical performance indicators such as total and/or high-speed running distance,[8, 9] the acute physiological responses following second-half match introduction are unclear. Therefore, this study profiled the physiological and performance responses to typical substitute-specific pre-pitch-entry preparations, while assessing the effects of simulated partial match-play.

Methods

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

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

Isolated performance testing was conducted post-warm-up (within five min), before an ~85 min transition period. This time was mostly spent seated, wearing normal training attire and viewing standardised footage of soccer match-play on a mobile tablet device (iPad, Apple, USA), but was punctuated at ~25 min (RWU1), ~50 min (half-time RWU), and ~70 min (RWU2), by ~5.3 min of rewarm-up activity.[8, 9, 13] Rewarm-ups were performed within a narrow space that reflected a typical pitch side-line area, and included dynamic stretches alongside low- to moderate-intensity movements.[8, 9] Further performance testing (i.e., pre-SMS) took place ~10 min after RWU2, before ~30 min of the soccer match simulation (SMS[14]) requiring participants to perform five ~4.5 min 'blocks' of exercise (i.e., block one to block five) separated by two min passive rest.

Sprint time (15 m) was repeatedly assessed as part of the SMS, whereas isolated 15 m sprint times and countermovement jump (CMJ) performances were tested post-warm-up, immediately pre-SMS, and post-SMS. Each CMJ commenced in a standing position, from which participants performed a preparatory 'dip' before explosively jumping to attain maximum height. Hands remained on hips throughout. A portable force platform (FP4060-05-PT; 1000 Hz, Bertec Corporation, USA) provided vertical force-time data, from which peak power (PP) output and jump height (JH) were calculated.[15, 16] For sprint assessments, participants sprinted as fast as possible from a static start through markers placed 20 m away, with timing gates (Brower TC-System; Brower Timing Systems, USA) at 0 m and 15 m.

An ingestible sensor (CorTemp™; HQ Inc, USA) allowed T_{core} to be assessed pre- and post-warm-up, before and after each rewarm-up, pre-SMS, and after every ~4.5 min block of the SMS. This method is safe, valid, and reliable[17] and, as per the manufacturer's guidelines, sensors were consumed at least three hours before the first measurement. Capillary blood samples, analysed for glucose and lactate concentrations (YSI 2300 STAT PLUS; Yellow Springs Instruments, USA), were taken pre- and post-warm-up, before each rewarm-up, pre-SMS, and after ~15 min and ~30 min of simulated match-play. Heart rate was continuously recorded during exercise (Polar T31; Polar Electro, Finland), whilst participants indicated subjective ratings of perceived exertion (RPE; 6-20)[18] for the warm-up, each rewarm-up, and every block of the SMS. Pre- to post-trial changes in urine osmolality (Osmocheck; Vitech Scientific, UK) and fluid-corrected body mass were determined.

Statistical analyses were conducted using SPSS (Version 21.0; SPSS Inc., USA), with significance established when $p \leq 0.05$. One-way repeated measures analyses of variance were used to assess whether 'time' influenced physiological and performance responses. Mauchly's test was consulted, and the Greenhouse-Geisser correction applied if the assumption of sphericity was violated. Significant time effects were investigated via post-hoc Bonferroni-adjusted pairwise comparisons, whilst changes in body mass and urine osmolality were assessed using paired t-tests. Cohen's d effect sizes (ES) were calculated for post-hoc comparisons where $p \leq 0.05$, and were interpreted as: 0.00-0.19, *trivial*; 0.20-0.59, *small*; 0.60-1.20, *moderate*; 1.21–2.0, *large*; and >2.01, *very large* effects.[19] Where necessary, mean data from the corresponding time-point was imputed for any missing values.[20]

Results

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

****INSERT FIGURE 1 HERE****

Time also influenced isolated 15 m sprint times ($F_{(2,24)}$ =6.275, p =0.006, partial-eta^2 =0.343), as well as CMJ PP ($F_{(2,24)}$ =14.389, $p \leq 0.001$, partial-eta^2 =0.545) and JH ($F_{(2,24)}$ =5.92, p =0.008, partial-eta^2 =0.33). Isolated sprints performed pre-SMS (2.54±0.12 s, p =0.003, ES: 0.77) were slower than those performed post-warm-up (2.44±0.13 s), whereas post-SMS times (2.51±0.10 s) remained unchanged from pre-SMS values. Post-warm-up CMJ responses (PP: 4088±884 W, JH: 32.7±5.7 cm) exceeded pre-SMS values (PP: 3792±873 W, JH: 29.6±4.8 cm) for both PP ($p \leq 0.001$, ES: 0.34) and JH (p =0.017, ES: 0.58). Increased PP (p =0.006, ES: 0.33) was observed from pre-SMS to post-SMS (4086±913 W), whereas sprint performances remained unchanged throughout exercise.

****INSERT TABLE 1 HERE****

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

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

SMS (207±153 mOsm·kg^{-1}) had decreased ($t_{(12)}$ =5.175, p ≤0.001, ES: 2.2) from pre-warm-up (657±259 mOsm·kg^{-1}).

****INSERT FIGURE 2 HERE****

Discussion

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

Whilst T_{core} was elevated by the initial warm-up, this response had dissipated well in advance of the simulated second-half pitch-entry. Several investigations highlight rapid declines in body temperature when periods of inactivity follow exercise;[6, 12, 21] responses that are typically accompanied by decreases in physical performance capacity and potential elevation of injury-risk factors (e.g., reduced dynamic eccentric hamstring strength).[6, 12, 21] Contrary to studies reporting reductions within ~10-15 min of exercise cessation,[6, 21] T_{core} was maintained relative to post-warm-up values until the start of half-time (~50 min). Where ≥15 min separates the end of the pre-match warm-up and a player's introduction into a match, performing short bouts of rewarm-up activity may help to preserve body temperature and attenuate declines in explosive physical performance compared with passive rest.[3] Although values did not increase significantly from pre-RWU1 to post-RWU1, it is possible that RWU1 may have helped to slow the rate at which T_{core} declined following warm-up cessation. Notwithstanding, T_{core} declined from post-warm-up and had returned to pre-warm-up levels prior to simulated pitch-entry, whilst CMJ and 15 m sprint performances worsened during this time. Acknowledging that rewarm-up practices may vary,[1] replicating the pattern of activities performed by professional soccer substitutes[8] did not maintain T_{core} and physical performance responses from post-warm-up values until the time of pitch-entry in thermoneutral conditions. Such findings suggest that modifying the pre-pitch-entry activities currently adopted by substitute players warrants further investigation.

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

Rewarm-up strategies reflected the fact that practical and regulatory barriers may modulate the activities that substitutes can perform between kick-off and pitch-entry.[1] The design of modern stadia often limits the space that is available for rewarm-ups, which could partly explain observations that professional substitutes covered <2 $m\cdot min^{-1}$ at >5.5 $m\cdot s^{-1}$ during each bout of pre-pitch-entry activity and did not exceed 7 $m\cdot s^{-1}$ at any time prior to match introduction.[8] Although theoretical, practitioners have postulated that providing more space within which to perform rewarm-ups may facilitate improvements in pre-pitch-entry preparations that could translate favourably into enhanced physical performance and/or reduced injury-risk thereafter.[1] Moreover, regulations in many competitions require team officials to remain within a designated technical area whilst match-play is underway.[25] Acknowledging that different teams provide substitutes with varying levels of guidance in relation to pre-pitch-entry strategies,[1] the content of any rewarm-up activity must ultimately be determined by the players themselves. Being named as a substitute has been associated with reduced motivation to prepare,[13, 26] whilst empirical observations highlight how events unfolding in the match appear to affect the self-selected activities performed by players awaiting pitch-entry.[8] As superior outcomes have been realised following coach-supervised compared with unsupervised training,[27] allowing members of team staff to accompany substitutes during rewarm-ups may enable more varied and better structured pre-pitch-entry preparations compared with when exclusively player-led activities are performed.[1]

Despite elevated blood lactate concentrations and progressive increases in RPE, sprint times were not reduced throughout ~30 min of simulated match-play. Acknowledging that adherence to audio signals to control exercise tempo precluded the adoption of self-pacing strategies in the present study, these observations conflict with match-play data whereby professional substitutes have demonstrated transient changes in physical outputs following pitch-entry.[8, 28] Bradley et al.[28] reported a tendency for total and high-speed running distances covered by substitutes to increase as the second-half progressed, whereas defining five min epochs relative to the moment of a player's introduction into a match (i.e., rather than relative to the match kick-off) highlighted up to ~39% reductions in physical outputs between the first and second post-pitch-entry epoch, before a plateau.[8] Speculatively, given that the current study highlights T_{core} declines from post-warm-up to pre-SMS, and that ~10 min of simulated match-play was required to restore T_{core} to post-warm-up values, it is possible that the observed match-play responses could reflect a pacing strategy that partly influenced by efforts to 'warm-up' having already entered the pitch. As a substitute's perceived ability to provide an immediate and sustained physical impact on a match is highly valued by soccer coaches and managers,[1] it is notable that increasing the amount of pre-pitch-entry activity performed by professional substitutes appeared to benefit initial physical outputs and reduce the magnitude of decline after match-introduction.[9]

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

Conclusion

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

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Legends

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

AU: Arbitrary units, HR: Heart rate, RPE: Rating of perceived exertion, RWU: Rewarm-up, SMS: Soccer match simulation, [a]: different from the initial warm-up, [b]: different from RWU1, [c]: Different from half-time RWU, [d]: Different from RWU2, [e]: Different from SMS block 1, [f]: Different from SMS block 2, [g]: Different from SMS block 3, [h]: Different from SMS block 4, [i]: Different from SMS block 5. A 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 ± standard deviation.

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

RWU: Rewarm-up, SMS: Soccer match simulation, [a]; Different from pre-warm-up, [b]: Different from post-warm-up, [c]: Different from pre-RWU1, [d]: Different from post-RWU1, [e]: Different from pre-half-time RWU, [f]: Different from post-half-time RWU, [g]: Different from pre-RWU2, [h]: Different from post-RWU2, [i]: Different from pre-SMS, [j]: Different from block 1, [k]: Different from block 2, [l]: Different from block 3, [m]: Different from block 4, [n]: Different from block 5. A 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 ± standard deviation.

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

RWU: Rewarm-up, SMS: Soccer match simulation, [a]; Different from pre-warm-up, [b]: Different from post-warm-up, [c]: Different from pre-RWU1, [d]: Different from pre-half-time RWU, [e]: Different from pre-RWU2, [f]: Different from pre-SMS, [g]: Different from block 3, [h]: Different from block 5. A 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 ± standard deviation.

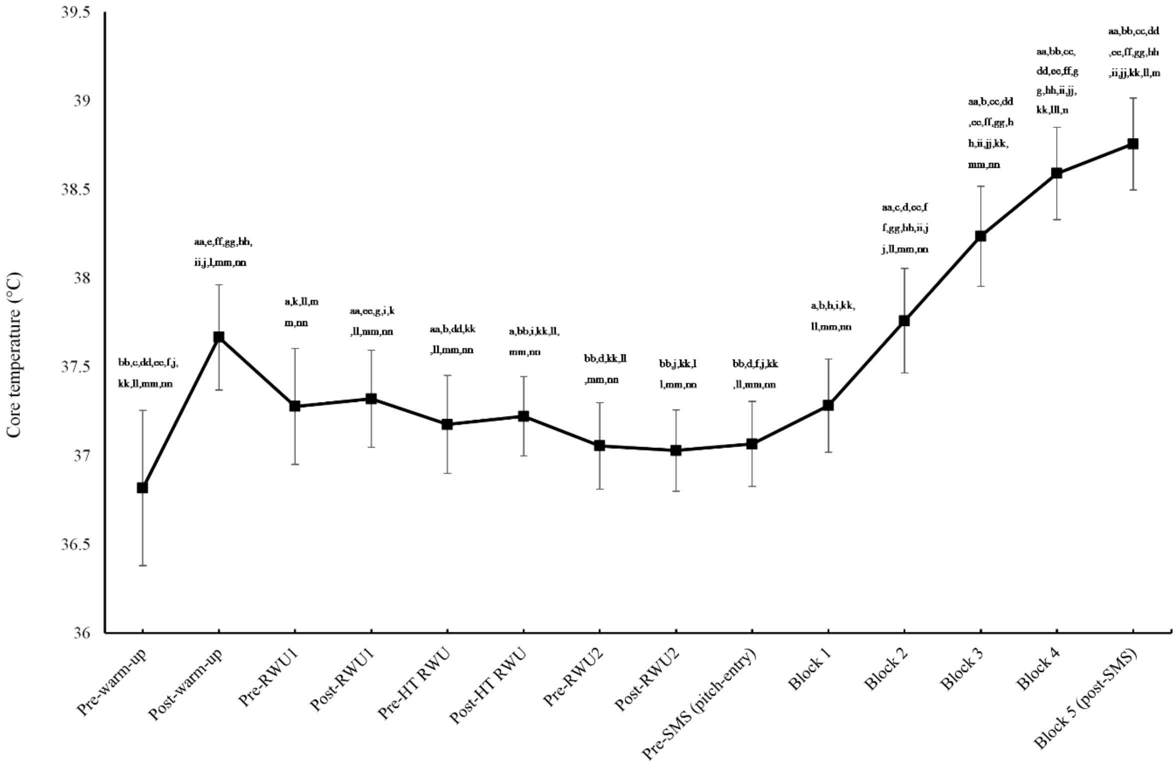

Figure 1: Time-course of changes in core temperature during a simulated match-day for substitutes (n=13).

RWU: Rewarm-up, SMS: Soccer match simulation, [a]; Different from pre-warm-up, [b]: Different from post-warm-up, [c]: Different from pre-RWU1, [d]: Different from post-RWU1, [e]: Different from pre-half-time RWU, [f]: Different from post-half-time RWU, [g]: Different from pre-RWU2, [h]: Different from post-RWU2, [i]: Different from pre-SMS, [j]: Different from block 1, [k]: Different from block 2, [l]: Different from block 3, [m]: Different from block 4, [n]: Different from block 5. A 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 ± standard deviation.

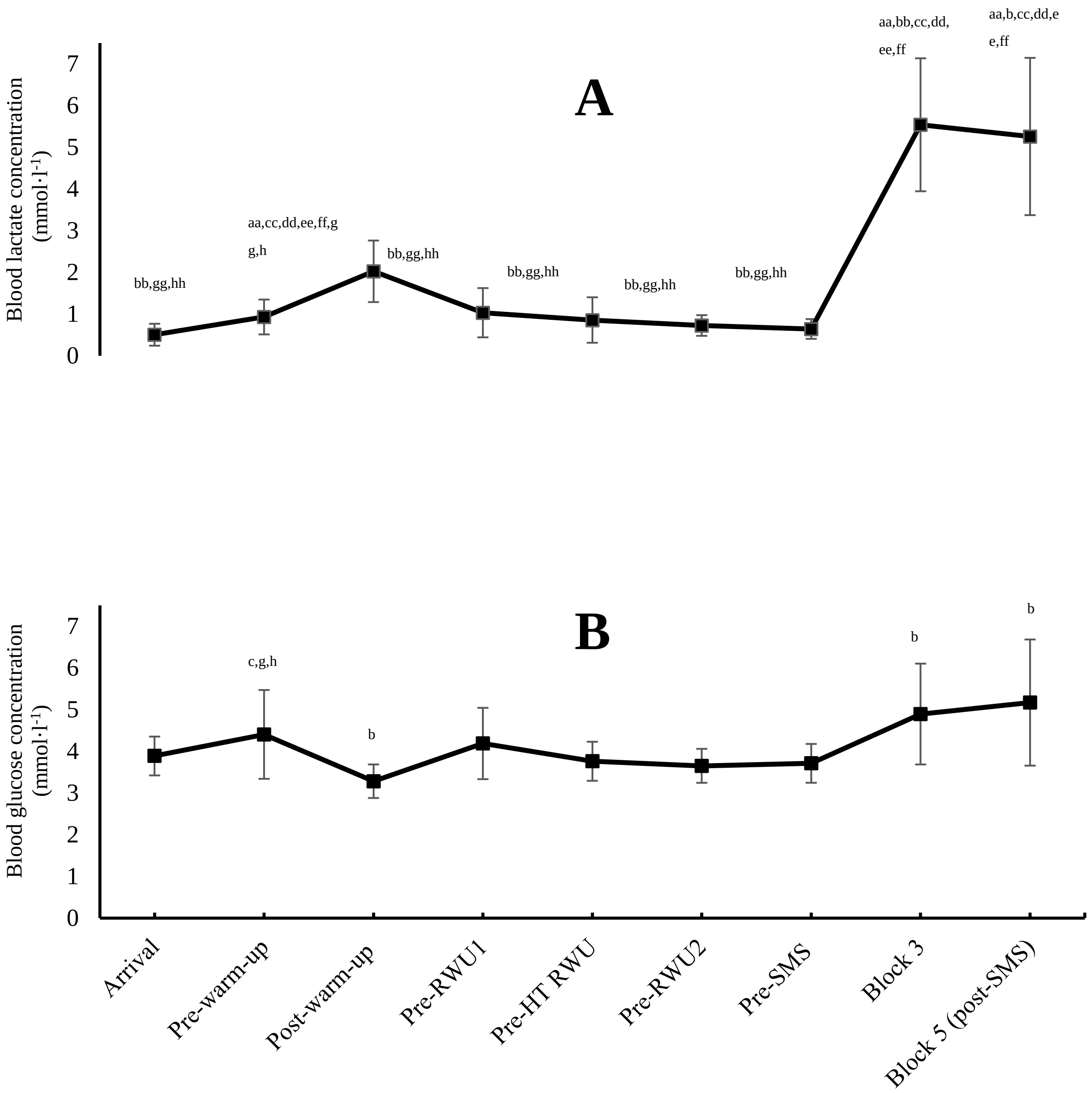

Figure 2: Time-course of changes in blood lactate (panel A) and blood glucose (panel B) concentrations during a simulated match-day for substitutes (n=13).

RWU: Rewarm-up, SMS: Soccer match simulation, [a]; Different from pre-warm-up, [b]: Different from post-warm-up, [c]: Different from pre-RWU1, [d]: Different from pre-half-time RWU, [e]: Different from pre-RWU2, [f]: Different from pre-SMS, [g]: Different from block 3, [h]: Different from block 5. A 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 ± 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
RPE (AU)	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,ii	16 ± 2 aa,bb,cc,dd,e,ff,h,i	17 ± 2 aa,bb,cc,dd,ee,ff,gg	18 ± 1 aa,bb,cc,dd,ee,ff,g
Mean HR (beats·min^{-1})	139 ± 10 bb,cc,dd,ee,ff,gg,hh,ii	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,hh,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
Peak HR (beats·min^{-1})	188 ± 9 bb,cc,dd	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
Mean HR (%$_{max}$)	69 ± 6 bb,cc,dd,ee,ff,gg,hh,ii	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,hh,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
Peak HR (%$_{max}$)	94 ± 6 bb,cc,dd	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
15 m SMS sprint time (s)	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, [a]: different from the warm-up, [b]: different from RWU1, [c]: Different from half-time RWU, [d]: Different from RWU2, [e]: Different from SMS block 1, [f]: Different from SMS block 2, [g]: Different from SMS block 3, [h]: Different from SMS block 4, [i]: Different from SMS block 5. A 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 ± standard deviation.