EXERCISE PHYSIOLOGY AND BIOMECHANICS

ORIGINAL ARTICLES

J SPORTS MED PHYS FITNESS 2007;47:263-9

Soccer half-time strategy influences thermoregulation and endurance performance

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Aim. In the first 15 min of the second half in professional soccer, there is a reduction of high intensity distance covered and a high incidence of injuries sustained, possibly due to a reduction in body temperature during the half-time (HT). The aim of this study was to investigate the effect of active and passive re-warm-up strategies on cardiovascular (heart rate, HR) and thermoregulatory stress, and second-half soccer-specific endurance performance (SSEP).
Methods. Seven professional players performed two intermittent field tests of 16.5 min duration, with a 15 min HT. On separate, randomised occasions, 4 trials were completed during which different HT strategies were undertaken between minutes 7 and 14 of the HT interval. Two passive trials were completed: rest control trial (CON), or players were immersed to the gluteal fold in a hot bath (~40 °C-passive heating, PH); in the active trials, players performed at 70% maximum HR, either steady-state non-specific active heating (cycling, NSAH) or intermittent soccer-specific active heating (sprinting repeatedly, SSAH). HR and core temperature (T_c) were measured every 5 min, and body weight was recorded pre and post each trial.
Results. Active re-warm-up strategies maintained SSEP in the second period with respect to CON ($P<0.01$), whereas PH did not reduce the decrement in performance ($P>0.05$). Active heating strategies increased HR during HT in comparison to CON, whereas PH did not. During the HT period in the CON trial, T_c decreased by 0.97±0.29 °C, PH and SSAH trials did not attenuate this decrease ($P>0.01$), whereas NSAH increased T_c in respect to CON ($P<0.01$). These differences in HR and T_c between re-warm-up strategies during HT were not apparent at the end of the trials.
Conclusion. Active re-warm-up strategies during HT attenuated the decrement in second-half SSEP that was observed during passive trials.

KEY WORDS: Exercises - Temperature - Re-warm-up.

Soccer activity is characterised by high-intensity intermittent exercise throughout two 45-min periods interceded by a 15-min half-time (HT) interval. This HT period has traditionally been used by coaches to relay tactical information and motivational encouragement to players in preparation for the second-half. More recently, the awareness of the physiological demands of match-play has increased, such that interventions to improve physical performance in the second-half have become much more common, such as fluid and glucose replenishment.[1]

In elite soccer, players usually warm-up for 25-30 min prior to the match. The benefits of a warm-up to prepare the players for the forthcoming physical activity include increased bloodflow[2] and temperature[3] to

Acknowledgements.—The authors would like to thank the coaches B. Russell and N. Mann, the physiotherapist C. More, and the players for their participation and co-operation. We would also like to thank Dr R. Polman for critical evaluation of the manuscript and A. Fisher and S Keatley for their technical work.

Received on July 19, 2006.
Accepted for publication on March 8, 2007.

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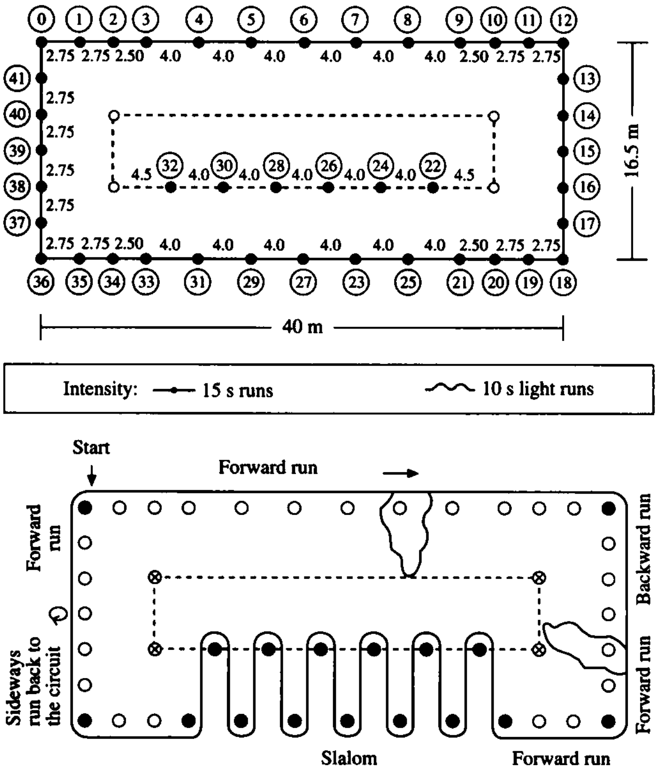

Figure 1.—The Bangsbo soccer field test circuit dimensions (A) and directions (B). [Adapted from Chamari *et al.*[16]].

the muscular tissues. The benefits of muscle temperature increase *per se* include the attainment of full soft tissue extensibility[4] and the enhancement of neuromuscular functioning, both of which would stimulate balance and co-ordination and potentially reduce the prevalence of muscular injury. Furthermore, a number of studies have observed an increase in high-intensity exercise performance with *a priori* warm-up.[5, 6] Although this practice is common-place before the start of a match, few teams undertake a re-warm-up at HT. During this 15 min interval, body temperature has been shown to decrease by ~1.1 °C[7] and muscle temperature has been shown to decrease by ~1.5 and ~2 °C in assistant referees[8] and elite soccer players,[7] respectively. Such a decrease in body and muscle temperature may result in impaired performance[5] or increased risk of muscle injury.[9] In the initial 15 min of the second half, high intensity running is performed less by players in comparison with the corresponding phase in the first half.[10, 11] Furthermore, previous researchers have observed an increase in the incidence of muscular injury of soccer players immediately after HT,[12, 13] and it is suggested that the decrease in muscle temperature maybe a contributing factor.[13, 14]

Recently, Mohr *et al.*[7] demonstrated that a moderate-intensity re-warm-up during the HT period attenuated the decrease in muscle temperature and sprinting performance observed subsequent to a typical passive recovery. However, to date no study has been undertaken to determine the effects of a re-warm-up on soccer-specific endurance performance (SSEP) during the second half. Furthermore, no studies have compared the effects of active and passive re-warm-up strategies on SSEP in the second half. Therefore, the aim of the current investigation was to determine the effects of passive and active heating strategies during the HT interval on second-half SSEP and the thermoregulatory response.

Materials and methods

Subjects

Seven elite young male soccer players were informed verbally and in writing as to the nature and risks involved in the study and all volunteered and gave written informed consent to participate. The study had ethical approval from the institutional ethics committee and conformed to the Declaration of Helsinki. All subjects were full-time academy players representing an English League One professional football club. The physical characteristics of the subjects (mean±standard deviation, SD) characteristics were: age, 17.4±0.5 years; weight, 69.1±3.1 kg; $\dot{V}O_{2max}$, 61.5±3 mL·kg·min^{-1}; Σ4 skinfolds: 26.9±4.3 mm.

Soccer-specific intermittent endurance test

The investigation consisted of an intermittent field test,[15] in which subjects moved around a football goal area using forwards, backwards and sideways running (Figure 1). Subjects were instructed to cover as much distance as possible during the test, which comprised of 40 15-s work bouts of 15 s interceded by 39 rest periods of 10 s. The Intermittent field test was performed twice interceded by a 15-min HT recovery period. The Bangsbo field test[15] is commonly used to assess soccer specific endurance,[16, 17] because it simulates the intermittent nature of soccer activity, using utility movement patterns that are also routinely used

TABLE I.—*Pre-exercise measures.*

	CON	PH	NSAH	SSAH
Laboratory temperature (°C)	19.6±0.8	19.3±0.5	20.6±1.1	20±1
USG	1.017±0.007	1.014±0.008	1.014±0.009	1.015±0.007
Pre-body weight (kg)	69.1±3.1	68.9±3.6	68.9±3.6	69.2±3.2

CON: control trial; PH: passive heating; NSAH: non-specific active heating; SSAH: soccer-specific active heating; USG: urine specific gravity.

in match-play. Furthermore, this test allowed for a first-half and second-half performance measure (distance covered), such that the efficacy of HT interventions could be investigated.

Half-time intervention strategies

During the HT interval, 4 experimental trials were conducted and were performed in a randomised manner. The protocols included: a seated rest control trial (CON), passive heating (PH), non-specific active heating (NSAH), and soccer-specific active heating (SSAH) trials. Each re-warming procedure was performed between 7 and 14 min, whereas the CON involved rest for the duration of the 15 min period. During the PH trial, subjects were immersed in 40 °C water up to the gluteal fold. The NSAH procedure involved the athletes cycling on an ergometer (Monark 824E, Sweden) at an intensity that elicited 70% HR_{max} that was recorded during the protocol. Conversely, the SSAH was composed of repeated agility sprint drills working at a work to rest ratio that elicited 70% HR_{max}. These exercises incorporated sprinting, bounding, jumping and other utility movements common to soccer match-play activity.

Physiological measures

Subjects attended the laboratory in a 3-h postabsorptive state having not consumed alcohol or caffeine in the 24-h period prior to testing. Players were asked not to perform strenuous exercise in the 4 h prior to arrival, and had to consume 500 mL of fluid 2 h before to ensure euhydration. Subjects were weighed and donated a urine sample prior to the intermittent endurance test to assess hydration status. Urine specific gravity (USG) was measured using a digital refractometer (Wolf Laboratories LTD, York, England). Body core temperature (T_c) was measured using a small ingestible temperature sensor pill, which had been taken 3 h prior to arrival at the laboratory. This pill transmitted temperature signals from the gut to an external receiver placed at the small of the back (CorTemp, HQ Inc., USA), and was measured at 5-min intervals during the exercise test and throughout the HT interval. Heart rate (HR) was monitored continuously throughout the duration of the test (Team System, Polar Electro, Finland). Upon cessation of the intermittent exercise test, the distance covered (metres) was calculated and the participants were re-weighed to determine sweat losses (kilograms).

Statistical analysis

Data is presented as mean±SD. A two-way mixed factorial (time x trial) repeated measures analysis of variance (ANOVA) was used to compare T_c, body weight changes, HR, and performance. Significant main effects were further analysed using paired-samples t tests. Statistical significance was accepted at the 95% confidence level ($P \leq 0.05$) unless adjusted by Bonferroni correction ($P \leq 0.013$).

Results

Repeated measures controls

The temperature of the laboratory was maintained between 18-21 °C for each of the four experimental trials, and did not differ between trials ($P>0.05$). Pre-exercise body weight and USG were measured to identify hydration status before exercise trials and these were not different for each laboratory visit (Table I; $P>0.05$).

Heart rate

Figure 2 shows the HR response for each of the four experimental trials. The mean HR for the players in the first and second halves of the CON was 181±7 and 180±8 beats·min^{-1}, respectively. This mean HR response corresponded to 92±4% of HR_{max} attained during the CON, and did not change between the first

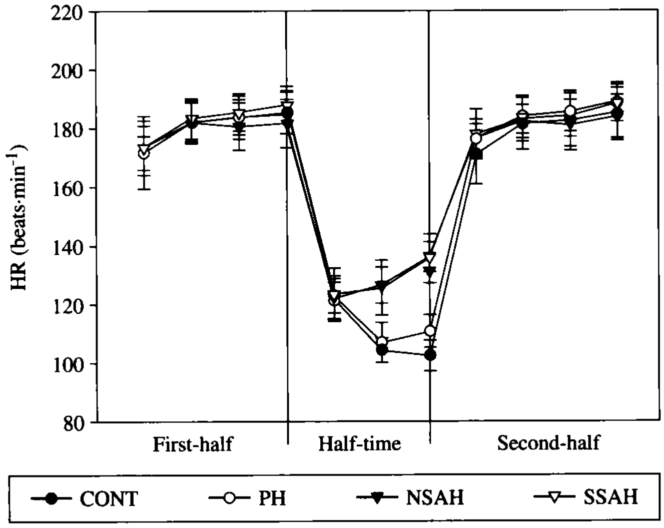

Figure 2.—Heart rate response for each experimental trial. CON: control trial; PH: passive heating; NSAH: non-specific active heating; SSAH: soccer-specific active heating.

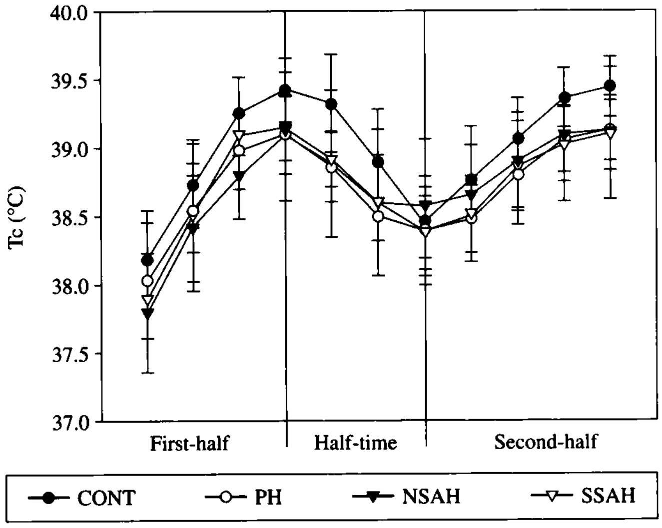

Figure 3.—Core temperature response for each experimental trial. CON: control trial; PH: passive heating; NSAH: non-specific active heating; SSAH: soccer-specific active heating.

and second halves in any of the experimental trials ($P>0.05$). The mean HR observed during the first half did not differ between experimental trials. Average HR during the HT period was significantly higher ($P<0.001$) during the NSAH (128±5 beats·min^{-1}) and SSAH (128±8 beats·min^{-1}) procedures compared with the control (110±4 beats·min^{-1}) and PH trials (113±6 beats·min^{-1}), However PH did not increase HR compared with the CONs ($P>0.05$). During the second period, no significant differences were observed for average HR ($P>0.05$), and therefore final HR was also similar between control, PH, NSAH and SSAH trials (185±9 *vs* 189±7 *vs* 184±7 *vs* 189±6 beats·min^{-1}, respectively; $P>0.05$).

Core temperature

Figure 3 shows the T_c response for each of the four experimental trials. The average T_c observed immediately prior to the first half for all of the experimental trials was 37.58±0.45 °C, and this increased to 39.18±0.33 °C at the end of this period ($P<0.01$). In the CON, T_c subsequently decreased to 38.45±0.26 at the end of the 15 min HT period ($P<0.01$). This rest-induced decrease in T_c of 0.97±0.29 °C was not significantly different from the change in T_c during PH (0.7±0.4 °C; $P>0.013$). In contrast, NSAH attenuated the decrease in T_c denoted during CONs (0.52±0.18 °C; $P<0.01$), and although not significant, SSAH also showed a trend toward limiting the rest-induced decreases in T_c (0.77±0.16 °C; $P=0.045$). Also of interest, was the trend toward a greater T_c decrement in SSAH *vs* NSAH ($P=0.05$). At the end of the second half, T_c was 39.44±0.22, 39.12±0.22, 39.1±0.48 and 39.1±0.27 °C in the control, PH, NSAH and SSAH, respectively. Final T_c in the CON showed a trend toward being greater than PH and SSAH ($P=0.023$ and 0.027, respectively), yet this did not reach statistical significance.

Weight loss

The weight loss of the players after the CON was 1±0.3 kg, which corresponded to 1.4±0.5% of pre-exercise body weight. Sweating rates for control, PH, NSAH and SSAH did not differ significantly ($P>0.05$) between trials (20.2±7.4 *vs* 26.2±5.1 *vs* 24.1±2.9 *vs* 22.3±2.9 mL·min^{-1}).

Distance covered

First half distance covered did not differ between the four experimental trials ($P>0.05$), which suggested that the players did not demonstrate a learning effect. In the CON, second half performance was decreased by 3.1±1.9% compared to the distance cov-

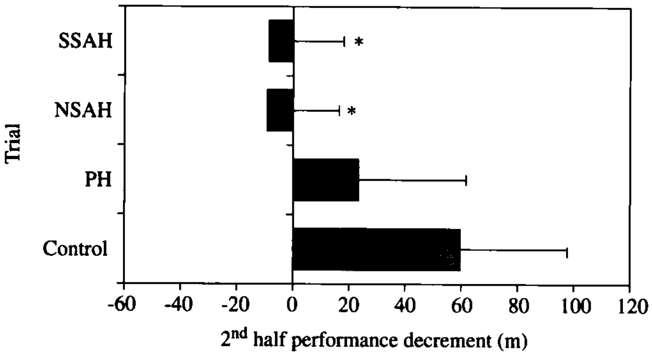

Figure 4.—Soccer-specific endurance performance decrement. SSAH: soccer-specific active heating; NSAH: non-specific active heating; PH: passive heating; CON: control trial. *: it denotes significantly lower than CON ($P<0.013$).

ered in the first half (Figure 4). Undertaking NSAH and SSAH during the HT interval significantly attenuated the decrement in the second half performance with respect to control procedures (-0.5±1.3%, -0.4±1.4%, respectively; $P<0.013$). Indeed, on average second half performance was greater than first half performance during these intervention trials, although these differences were not significantly different ($P>0.05$). PH during the HT period did not reduce performance decrement in the second half, in comparison to the CONs (1.2±1.9%, $P>0.013$).

Discussion

The primary finding of the current study was that an active re-warm-up performed during the HT period maintained SSEP (distance covered) in the second half. When the players were allowed to rest passively for the 15 min period, either seated at room temperature (18-21 °C) or standing whilst immersed in hot water (~40 °C), their second-half performance was decreased in relation to the first half. Interestingly, the physiological responses to the various re-warm-up strategies did not appear to contribute to the level of performance in the second period. Although HR was increased during both active heating methods (NSAH and SSAH) in comparison to passive methods (CON and PH), these differences were not observed at any time-point throughout the second half. At HT the reduction in T_c appeared to be minimised in active *vs* passive re-warm-up methods, yet the magnitude of these changes did not appear to affect T_c in the second period.

Previous research has shown that the prevalence of goals scored is increased in the initial period immediately after HT (OPTA Index, 2004). This may be caused by the decreased sprinting speed[7] and high-intensity running performed,[10, 11] and/or the impaired cognitive functioning[18] denoted during this period. Mohr *et al.*[7] discovered that after passive recovery during the HT interval, the sprinting performance was reduced by 2.4%. This sprinting performance decrement was not observed when the players undertook a moderate-intensity re-warm-up during HT. In the current study, the magnitude of the decrement in second half SSEP after passive recovery was 3.9% in CON, which concurs with the work of Mohr *et al.*,[7] such that physical performance characteristics in soccer can be enhanced with a moderate-intensity recovery phase. The current studies results extend these findings by suggesting that active, as opposed to passive re-warming, has a greater endurance performance benefit.

In the present study, PH did not increase T_c or HR in comparison to CON, and SSEP in the second half was decreased in relation to the first half by approximately 2%. The absence of significant increases in the physiological responses observed during this intervention suggests that this method was not sufficient to increase muscle and body temperature. In support, Drust *et al.*[19] showed that massage, as an alternative method of passive muscle heating, was not able to increase deep muscle temperature (3.5 cm) and, therefore, was also suggested to be unsuitable as a preparation strategy for exercise. In contrast, Gregson *et al.*[20] discovered that during a laboratory based intermittent protocol, PH to a critical T_c of 38 °C increased muscle and T_c during the first 45 min of activity with respect to CONs. Although HR did not increase with PH, Gregson *et al.*,[20] denoted that both passive and active heating decreased the body's capacity to store heat during the initial 45 min of exercise. However, the thermoregulatory responses to passive and active heating were shown to be short-term in nature during both sub-maximal steady-state,[21] and intermittent[20] exercise. These contrasting findings may be due to the different duration and intensity of PH exposures and further work is required to clarify this area.

In the present study, both methods of active heating negated the second-half SSEP decrement observed during passive trials. Since T_c and HR were increased during active as opposed to PH, it can be speculated that active heating increased muscle tissue blood flow[2] and temperature,[3] which may in part explain the improved performance in the second period with NSAH and SSAH. An increased muscle and body temperature for example, has been suggested to improve neuromuscular functioning, such as accelerated neural transmission rate[22] and time to peak tension.[23] Moreover, it has been suggested that if the active warm-up is sufficient to elevate baseline $\dot{V}O_2$, the subsequent accumulated oxygen deficit at the onset of exercise would be reduced. Thus, less of the initial work would be fuelled anaerobically, augmenting the anaerobic capacity later in the bout.[24] Therefore, the players in this study may have had a greater baseline oxygen uptake at the start of the second half, after an active re-warm-up, which could account for the increased SSEP observed in this investigation.

Few studies have investigated the effects of a task-specific warm-up on subsequent performance. In the current study, no performance differences between NSAH and SSAH were observed (-0.5±1.3 *vs* -0.4±1.4%, respectively). In contrast, Bishop *et al.*[25] found that an intermittent, task-specific warm-up increased kayak ergometer performance compared with a continuous warm-up. However, the authors did not discover any differences in $\dot{V}O_2$ or accumulated oxygen deficit between the two conditions and, therefore, suggested that the intermittent warm-up may have improved performance by means of improved neuromuscular functioning.

In the present investigation, although the NSAH and the SSAH re-warm-up strategies were of the same intensity (69.6±2.1%HR_{max} *vs* 69.2±2.8%HR_{max}), it was expected that the intermittent nature of SSAH would impose a greater thermal strain. However, we observed a trend toward a greater decrement in T_c over HT during SSAH as opposed to NSAH. This may be explained by the greater convective cooling during SSAH as opposed to stationary exercise, undertaken in NSAH. Since the physiological responses between the NSAH and the SSAH re-warm-ups were similar, differences in SSEP between the two interventions could not be expected. Perhaps performance benefits from task-specific warm-ups are only seen in short-term tasks, in which enhanced neuromuscular functioning is in part responsible, such as sprinting, jumping, and proprioception. Certainly, this area requires further investigation.

A number of investigations have observed an increase in the amount of injuries sustained during the second-half of match-play in soccer,[12, 13] and rugby union.[14] Hawkins *et al.*[12] analysed injuries during the 1994 World Cup in USA and found a particularly high incidence of non-contact injuries in the first 5 min of the second half in a number of matches, this was attributed to a failure to maintain muscle flexibility during the interval. Reilly *et al.*[14] identified a period of "vulnerability" to injury after starting the second half in rugby union, implicating a cool-down effect of HT. Furthermore, Rahnama *et al.*[13] used video analysis of 10 English premiership games, and showed that a relatively high number of injuries were incurred during the first 15 min of the second half, this being attributed to inappropriate warm-up after the interval. Although the current study did not quantify injury stratification, the suggestions made by previous investigations[12-14] that decreased muscle temperature and tissue extensibility may be contributing pre-cursers to injury, provides a substantial rationale for re-warm-up strategies at HT.

Participation in warm-up activities prior to an exercise bout has not always provided performance benefits, indeed some investigations have shown a decreased performance, especially in long-duration bouts.[21, 26, 27] Such an impaired endurance performance subsequent to a prior warm-up could be explained by depleted glycogen stores[28] and/or changes in hydration status, the latter of which may elevate circulatory[29] and thermal strain.[30] In the current study, there were no observed differences between the sweat rates in each trial, suggesting that hydration status was similar across trials and, therefore, did not account for variations in thermal strain and/or SSEP. Thermal strain may also be exacerbated by warm-up routines that increase T_c, which could inhibit prolonged exercise performance by decreasing the heat storage capacity[20, 21, 27] and an earlier development of a high T_c.[26] During the active heating trials employed in this study, thermal and cardiovascular strain were increased. However, upon cessation of exercise final HRs and T_cs were not different to CON and PH. Therefore, despite the development of a high HR (~185 beats·min^{-1}) and T_c (39.2 °C) at the end of the second-half, the increased thermoregulatory response denoted during active heating trials did not attenuate endurance performance. These results contrast with previous work, which suggested that pre-warming decreased endurance performance during continuous[21] and intermittent exercise.[27] One reason for the disparity between these results may be the relatively short-duration (16.5 min) of the soccer-specific endurance protocol used in the current investigation.

Conclusions

In summary, the present study demonstrated that passive recovery during HT reduced T_c and SSEP in the second half. Participation in a moderate-intensity, active re-warm-up at half time increased T_c and maintained SSEP. Since the initial period after the HT interval is associated with a high prevalence of injury and a reduced high intensity distance covered, a HT active re-warm-up sufficient to increase muscle and body temperature has numerous performance benefits.

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