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Original Article

Effect of hot environmental conditions on physical activity patterns and temperature response of football players

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Heat stress may contribute to decreased match performance when football is played in extreme heat. This study evaluated activity patterns and thermal responses of players during soccer matches played in different environmental conditions. Non-acclimatized soccer players ($n = 11$, 20 ± 2 years) played two matches in conditions of moderate heat (MH) and high heat (HH) index. Core temperature (T_c) and physical performance were measured using a telemetric sensor and a global positioning system, respectively. The average ambient temperature and relative humidity were MH 34 ± 1 °C and $38 \pm 2\%$; HH 36 ± 0 °C and $61 \pm 1\%$. Peak T_c in the MH match was 39.1 ± 0.4 °C and in the HH match it was 39.6 ± 0.3 °C. The total distance covered in the first and second halves was 4386 ± 367 and 4227 ± 292 m for the MH match and 4301 ± 487 and 3761 ± 358 m for the HH match. Players covered more distance ($P < 0.001$) in the first half of the HH match than in the second half. In football matches played at high environmental temperature and humidity, the physical performance of the players may decrease due to high thermal stress.

Soccer is the most popular sport in the world and is played regardless of age, gender and physical capacity. The physical aspects of soccer have been studied most intensively in adult male players and a substantial body of information is available for this population (Mohr et al., 2003; Bangsbo et al., 2006). In a typical soccer match, elite players cover a total distance of 9–12 km with an average aerobic loading of 75% of maximum oxygen uptake (VO_{2max}) and at about 80–90% of maximum heart rate (HR) (Krustrup et al., 2005; Stølen et al., 2005; Bangsbo et al., 2006). From published studies, it is clear that soccer performance, and thus match outcome, may be determined by the ability to perform repeated short bursts of high intensity work against an endurance background.

Football is played in many different environments and, in some parts of the world, competitive matches are played in challenging conditions where the temperature may exceed 30 °C with a high relative humidity. Hyperthermia imposes upon the player an extra burden of thermal stress that is added to the physical stress. The player's body core temperature rises, sweating rate increases as physiological defence mechanisms are invoked to dissipate the heat load and reduce the thermal stress and fatigue ensues (Nybo, 2008). The combination of an increase in body core temperature and progressive dehydration causes the soccer player to become more exhausted, leading to fatigue and more important than fatigue, the potential for adverse effects upon the player's health. Pyke and Hahn (1980) reported a mean core temperature of 39.9 °C in players at the end of an Australian Rules football game played at an ambient temperature of 38 °C, and hence some individual values would have been well in excess of 40 °C. The thermal stress that players face during a match has typically been estimated by match simulation in laboratory or controlled indoor environments (Drust et al., 2000; Nicholas et al., 2000) However, soccer incorporates frequent fluctuations between high and low exercise intensities with a change in activity every 4–6 s (Stølen et al., 2005), and hence the physical activity pattern of soccer may be quite different from the activities typically performed in laboratories. In addition, measurements made after the completion of a game may not truly reflect the changes in core temperature occurring during the game.

The effects of heat stress or dehydration, either separately or in combination, may contribute to a decrease in match performance (Shirreffs et al., 2006). A variety of different methods are used to evaluate the activity patterns and the physiological strain of match play. These methods include the monitoring of HR responses (Lothian & Farrally, 1992), blood lactate accumulation (Bangsbo et al., 1991) and thermal responses (Maughan & Leiper, 1994). The activity patterns and the distance covered have been assessed via match notation and motion analysis methods (Duthie et al., 2003; Di Salvo et al., 2006; Roberts et al., 2006). All these methods have limitations, including the cost of the method used, expertise of the analyst, time to analyze the raw data and the compliance of players, management and match officials. Global positioning systems (GPS) offer an alternative method of assessing activity patterns in the field of sports. GPSs were originally developed as a military tool and were funded by U. S. Department of Defense for strategic purposes. The system consists of 24 operational satellites, each of which orbits the earth twice daily on one of six paths and is equipped with an atomic clock that transmits the exact time and the position of the satellite. The GPS receiver compares the time signal from each satellite within range. The lag time measured by the receiver is translated into distance, and the exact position of the receiver on the Earth's surface can be determined in three dimensions by calculating the distance to at least four satellites (Townshend et al., 2008). This methodology has been applied to movement analysis of player of various levels of ability (Mohr et al., 2003), but time–motion analysis has not yet been used to establish how players' match performance is affected by environmental conditions. This study was designed to evaluate the change in the activity patterns of players during soccer matches played in different conditions of environmental temperature and humidity.

Materials and methods

Subjects

The study received prior approval from the Cukurova University ethics committee, and players provided written informed consent to participate after reading a document describing the nature, benefits and possible risks of the study. Eleven male semi-professional soccer players [mean (SD) age 20.4 (2.1) years, height 176.8 (4.8) cm, weight 68.5 (5.3) kg, body fat percent 13.4 (2.2)% and VO_{2max} 62.6 (6.8) mL/min/kg] agreed to participate this study. Two competitive matches were played the city of Adana in June and July 2007. The players all lived in Ankara, which is located about 480 km northwest of Adana, and traveled to Adana 3 days before the soccer match. The daily 24-h average ambient temperature and relative humidity of Adana were 26 °C and 69% in June and 28 °C and 68% in July, respectively. The average temperature and humidity of Ankara were 20 °C and 45% in June and 23 °C and 30% in July (http://www.meteor.gov.tr). The players were not heat acclimated before the first match and they did not perform any intense training in the few days before or between the matches. The goalkeeper's results are not presented in this manuscript due to the different nature of his activity. In the June match, one GPS device was damaged by a collision between players; hence GPS data were obtained for nine players. The core temperature and urine specific gravity were measured from 10 subjects in June. The number of players taking part in the first and second halves of the July match was eight and six, respectively. In the first half, two players did not play due to gastrointestinal (GI) system complaints and in the second half, one player left the game because of GI complaints and the other player because of an injury. The missing players were replaced with players from a local soccer team. Core temperatures were measured from eight players in the first half and six players from the second half of the July match. GPS data and urine specific gravity data were taken into account from the six players who played in both halves of the July match.

Preliminary measurements

Before the experimental trials, maximum oxygen uptake (VO_{2max}) was determined from a progressive intensity and continuous effort treadmill protocol. Pulmonary VO_2 was measured on-line using a breath-by-breath cardiopulmonary exercise testing system (Cosmed Quark b^2, Cosmed, Rome, Italy). Subjects started walking on a motorized treadmill (T-15, Cosmed) at 5 km/h with speed increments of 1 km/h every minute until they could no longer keep pace. Gas analyzers were calibrated before each test with ambient air and a gas mixture of known composition. The facemask, which had low dead space, was equipped with a low-resistance, bidirectional digital turbine (28 mm diameter), which was used to measure ventilation volume. The turbine was calibrated before each test with a 3 L syringe (Cosmed). During the incremental testing period, HR was monitored continuously using a wireless HR monitor (S610i, Polar, Finland) and was synchronized to ventilatory signals. The criteria for attaining VO_{2max} included the participant reaching volitional exhaustion, an HR within 10 beats per minute of age-predicted maximum HR and a respiratory exchange ratio of 1.15 or more (Bird & Davison, 1997).

Core temperature measurement

Core temperature (T_c) was monitored using a VitalSense® telemetric physiological monitoring system (Mini Mitter Co. Inc., Bend, Oregon, USA), which consists of a receiver and a thermistor-based, ingestible Jonah core temperature sensor capsule. As reviewed extensively by Byrne and Lim (2007), the ingestible telemetric temperature sensor represents a valid index of core temperature measurements. The validity of self-calibrated sensors and core body temperature monitoring systems had been shown by McKenzie and Osgood (2004). Sensors were activated approximately 4 h before the match and swallowed immediately after activation. By the time of the soccer match, the sensors would have passed through the stomach and the temperature measurements would not be substantially affected by the ingestion of hot or cold liquids. All the swallowed thermosensor pills were checked before the match to ensure the device residing in the player was transmitting a signal. Signals from the sensor were collected just before the match to record initial core temperature values.

GPS with HR measurement

GPS monitors were used to record HR via a chest strap (Forerunner 305, Garmin, Southampton, UK). The players started the stopwatch with the starting signal of the referee. During the body core temperature measurements, time periods were marked to indicate the exact time of measurement for further analysis of the HR and speed change.

Soccer match play

All players swallowed the activated thermosensor about 4 h before the match. Three hours before the match, subjects ate a small standardized meal and drank only water. To ensure that all subjects were hydrated at the beginning of each game, they were encouraged to drink water liberally the night before the game. Approximately 45 min before the start of the match, a baseline urine sample was collected before the players, wearing only underwear, were weighed to the nearest 50 g using a digital scale. Urine samples were analyzed for urine specific gravity using reagent strips (Arkray Aution Sticks EA IVD for urine strips, Arkray Inc, Kyoto, Japan). During the match, one investigator from the research team entered the football field and recorded time, HR and body core temperature without any interruption to the game. HR and temperature measurement were recorded in about 30 s and the player rejoined the match. During the match period, all players had free access to plain water from their individually identified drinking bottles, which were weighed before and after the game and replaced as necessary during the game. Players consumed water *ad libitum*. Body mass measurements were repeated immediately after the game. The amount of body weight change was defined as dehydration. The change in body mass, corrected for fluid intake and urine output, was used to estimate sweat loss. Metabolic fuel oxidation, metabolic water gain and respiratory water losses were not accounted for in this calculation (Maughan et al., 2007a).

The ambient temperature and relative humidity were recorded at the side of the playing field every 10 min during each game by a meteorologist from the Turkish Regional Meteorology Department. The heat index (HI) was calculated by combining air temperature and relative humidity to determine the effective temperature (http://en.wikipedia.org/wiki/Heat_index#Formula).

Match analysis

Just before the start of the game, the GPS monitoring devices were turned on. All the players marked the time of the beginning of the match with the signal of the referee. At the end of the match, the watches were collected from the players and the data were transferred to a computer for further analysis. A computer-based analysis program (Cycling Peaks WKO+, Lafayette, Colorado, USA) was used to evaluate HR and speed changes during the match. The following locomotor categories were used: standing (0–0.4 km/h), walking (0.5–7.5 km/h), jogging (7.6–14.5 km/h), low–moderate running (14.6–19.5 km/h), high-speed running (19.6–25.5 km/h) and sprinting (>25.6 km/h). The locomotor categories were chosen in accordance with Di Salvo et al. (2007). The above categories were later divided into four categories: (1) standing; (2) walking; (3) running, encompassing jogging and low–moderate intensity running and (4) high-intensity running, consisting of high-speed running and sprinting.

Statistical analysis

Values are reported as mean ± standard deviation. Statistical significance was accepted as $P < 0.05$ with a confidence interval of 95%. One-way ANOVA was performed to test the differences between experiments performed in June and July. Pre- and post-match variations within the experiment were evaluated with paired samples *t*-test. Relationships between body core temperature and the difference in the total distance covered were investigated by Pearson correlations.

Results

Meteorological measurements

The average ambient temperature for the June match was 34 ± 1 °C with a relative humidity of 38 ± 2%. In the July match, average ambient temperature was recorded as 36 ± 0 °C with a relative humidity of 61 ± 1%. According to the HI calculation (http://en.wikipedia.org/wiki/Heat_index#Formula), HI for the June and July matches was 35 ± 1 and 49 ± 1 °C, respectively. The HI was significantly higher in July [high heat (HH) index] than in June [moderate heat (MH) index] ($P < 0.001$). The MH and HH matches were played at 15:10 and 16:00, respectively.

Body core temperature measurements

Players began the two matches with similar body core temperatures as measured after their warm up had been completed (37.6 ± 0.3 and 37.7 ± 0.4 °C for MH and HH matches, respectively). Body temperature rose significantly compared with initial T_c values in both games, with the highest values being recorded in the HH match: individual values as high as 40.2 °C were recorded at the half time of the game. However, the difference between matches in T_c values became significant about the 35th minute in the first half. Peak T_c values recorded in the last 10 min of the first halves were 39.1 ± 0.4 and 39.6 ± 0.3 °C for the MH and HH matches, respectively (Fig. 1). In both games, core temperatures fell during the half-time

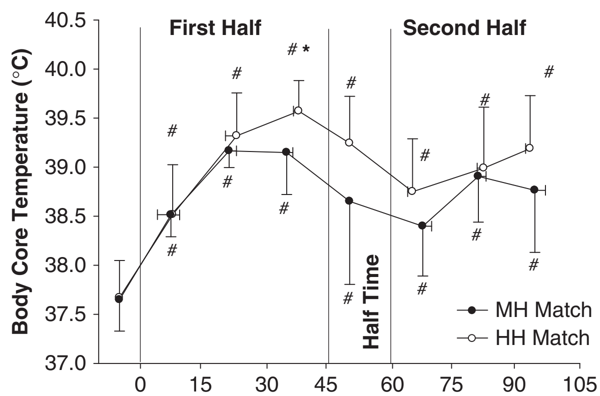

Fig. 1. Average core temperature of the players vs time for the MH and HH matches (mean ± standard deviation). *Significant difference between the MH and HH matches ($P < 0.05$). #Significantly higher match values than initial values of the corresponding match ($P < 0.005$). MH, moderate heat; HH, high heat.

break, and did not return to the peak first half level during the second half of the match.

Match analysis

The total distance covered during the MH and HH matches was 8613 ± 584 m (range 7493–9190 m) and 8155 ± 731 m (range 7122–8888 m), respectively. The amount of time during the game spent on standing, walking, jogging, low–moderate-speed running, high-speed running and sprinting is shown in Table 1.

The mean time spent in jogging and low–moderate-speed running was lower in the HH match than in the MH match ($P < 0.05$), whereas the percentage of walking time was higher in the HH match ($P < 0.001$; Table 1). The percentage of low–moderate-speed running distance in the HH match was lower than in the MH match ($P < 005$), whereas the percentage and mean distance of walking in the HH match were higher than in the MH match ($P < 0.05$; Table 2).The total distance covered in the first and second halves was 4386 ± 367 and 4227 ± 292 m for the MH match and 4301 ± 487 and 3761 ± 358 m for the HH match, respectively. There was no difference in distance covered between the two halves of the MH game, but players covered less distance ($P < 0.001$) in the second half of the HH match than they did in the first half (Fig. 2).

In the MH game, players covered 75 ± 30 m at full sprinting speed in the first half and only 32 ± 22 m in the second half ($P < 0.05$). In the HH match, sprinting distances for the first and second halves were 45 ± 37 and 63 ± 34 m, respectively. The players' high-speed running distances for the first and second halves of the MH game were 203 ± 46 and 180 ± 82 m, respectively, while the corresponding distances for the HH match were 194 ± 97 and 132 ± 52 m, respectively. When sprinting and high-speed running distances are combined to calculate high-intensity running distance, players covered 271 ± 70 and 214 ± 83 m for the first and second halves in MH and 236 ± 127 m in the first and 196 ± 80 m in the second half in HH match.

The distance covered at low–moderate-speed running in the first half of the HH match was

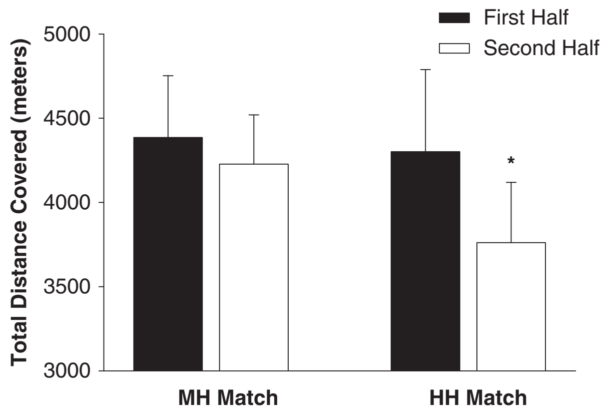

Fig. 2. Total distances covered in first and second halves of MH and HH matches. *The significant difference between first and second halves of HH match ($P < 0.001$). MH, moderate heat; HH, high heat.

Table 1. Mean duration and percent of time spent on the locomotor categories for MH and HH matches (mean ± SD)

	Standing	Walking	Jogging	Low–moderate speed running	High-speed running	Sprinting
Mean duration (min)						
MH match	8.0 ± 1.5	66.7 ± 4.8	19.2 ± 3.1	3.8 ± 0.8	1.2 ± 0.3	0.2 ± 0.1
HH match	7.7 ± 2.3	64.7 ± 3.5	14.7 ± 4.0*	2.5 ± 0.8*	0.9 ± 0.4	0.2 ± 0.1
Percentage of total time						
MH match	7.4 ± 1.3	61.2 ± 3.7	17.4 ± 3.0	3.4 ± 0.8	1.1 ± 0.3	0.2 ± 0.1
HH match	8.5 ± 2.5	71.4 ± 3.8#	16.2 ± 4.4	2.8 ± 0.9	1.0 ± 0.5	0.2 ± 0.1

*Statistically different from the MH match ($P < 0.05$).
#Statistically different from the MH match ($P < 0.001$).
MH, moderate heat; HH, high heat.

Table 2. Total distances and percent of total distance covered with different locomotor categories for MH and HH matches (mean ± SD)

	Standing	Walking	Jogging	Low–moderate running	High-speed running	Sprinting
Mean distance (m)						
MH match	12 ± 2	4147 ± 292	3035 ± 510	934 ± 2207	382 ± 99	102 ± 44
HH match	10 ± 4	4496 ± 364*	2513 ± 664	694 ± 224	334 ± 152	108 ± 59
Percentage of total distance						
MH match	0.1 ± 0	48.4 ± 5.1	35.1 ± 4.1	10.8 ± 2.0	4.4 ± 1.1	1.2 ± 0.5
HH match	0.1 ± 0.1	55.5 ± 6.6*	30.5 ± 6.0	8.4 ± 2.2*	4.1 ± 1.8	1.3 ± 0.7

*Statistically different from the MH match ($P < 0.05$).
MH, moderate heat; HH, high heat.

significantly shorter than in the first half of the MH match ($P<0.05$). Jogging distance in the second half of the HH match was significantly shorter than the first half of the HH and second half of the MH matches ($P<0.05$). When the distances covered with running (consisting of low–moderate-speed running and jogging) are compared, the distance covered in the second half of the HH match was significantly shorter than the first half of HH match and second half of MH matches ($P<0.05$). The walking distance covered in the first half of the match played in HH match was significantly higher than the first half of the match played in MH match.

The relationships between body core temperature measured at the end of the first half and the differences of the total distance covered in first and second halves of MH and HH matches are given in Fig. 3. The bivariate correlation between T_c and differences in total distance covered was not significant in either match.

HR

Average HR in the first half of the MH match was higher (171 ± 11 beats per min, $P<0.05$) than in the second half (164 ± 9 beats per min). In the HH match, players' mean HR in the first half (169 ± 11 beats per min) was also higher ($P<0.05$) than in the second half (155 ± 17 beats per min).

Change in body mass

Players' body mass loss (expressed as a percentage decrease from the pre-game mass) was similar at the end of the MH and HH matches (2.3 ± 0.7 and 2.1 ± 0.7% for MH and HH matches, respectively). Pre-match urine specific gravity was lower ($P<0.05$) for the MH match (1.024 ± 0.007) than for the HH match (1.030 ± 0.000). Sweating rates were estimated from mass loss, urine output and fluid intake without accounting for substrate exchange and other losses that would have only a minor effect at these high sweat rates (Maughan et al., 2007a). Estimated sweat rates were 1.9 ± 0.3 L/h for the MH match and 2.0 ± 0.3 L/h for the HH match.

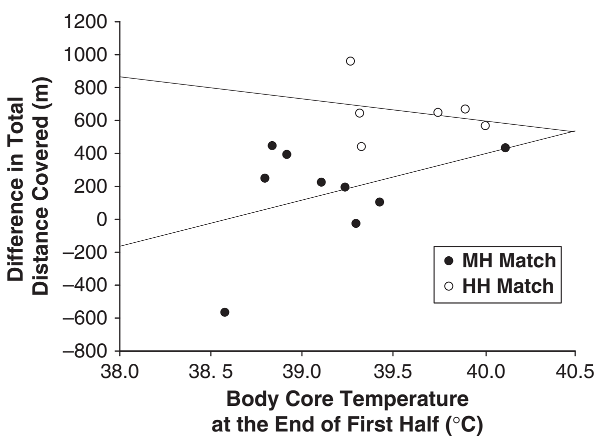

Fig. 3. Body core temperature recorded at the end of the first half of the match vs difference in the total distance covered in first and second halves of the MH) and HH matches. The correlation between body core temperature and difference in total distances covered was not significant for MH and HH matches ($r^2 = 0.164$, $P = 0.28$ for the MH match, $r^2 = 0.07$, $P = 0.62$ for the HH match). MH, moderate heat; HH, high heat.

Discussion

It is well recognized that hyperthermia is a common occurrence during football match play, and that the highest core temperatures are commonly reached in games played in hot and humid conditions. Severe heat stress is unusual in soccer, but there are potentially serious consequences of hyperthermia, and in a single youth soccer tournament played in hot conditions in the United States, a total of 34 players collapsed as a consequence of heat exhaustion (Kirkendall, 1993). Post-match rectal temperatures in excess of 39 °C are common, and in an unpublished report of a Swedish first division match quoted by Bangsbo (1993), all players had a rectal temperature in excess of 39 °C at the end of the game. Some individual values in excess of 40 °C have been recorded (Smodlaka, 1978; Ekblom, 1986), and such high values must be a cause for concern. In all of these competitive match situations, core temperature was measured as rectal temperature, with measurements being made as soon as was practical after the end of the game.

Results from the present study show high values for core temperature similar to those reported previously for games played in the heat. In the present study, however, peak T_c was recorded at about the 30th minute of the match at values of 39.1 ± 0.4, and 39.6 ± 0.3 °C for the MH and HH matches, respectively. Although the mean values for the both matches are about 39–39.5 °C, in each match, one individual player reached peak T_c values high as 40.2 °C. This suggests that the measurement of core temperature after the conclusion of games played in conditions of high heat and humidity may not reflect the peak temperature reached during the game. Edwards and Clark (2006) have also used the ingestible pill system to obtain values for core temperature during the course of games. In one of their games, measurements were made on eight players in a recreational game that was played at an ambient temperature of 16 °C, while the other, a competitive English league game ($n = 4$ players), was played at an ambient temperature of 19 °C. High thermal stress would not be expected in these games, but the mean core temperature was about 39.5 °C at the end of the recreational game and 38.8 °C at the end of the professional game. In both games, the highest temperatures were recorded at the end of the game, but in the professional players, there was no significant increase in temperature from half time to the end of the game. In this study, ambient temperature and relative humidity were used to calculate the HI. Although solar radiation is an important contributor to determine heat load, it was not measured in our study. Even though the main difference in MH and HH matches seems to be relative humidity, we should keep in mind that solar radiation may also be an important factor.

In the present study, core temperature increased rapidly from kick off on both games, and the rate of increase was not apparently different during the first 15–20 min of play, even though there was a significant difference in the environmental HI. In the second quarter of the game, however, there was little further increase in core temperature in the MH game, but it continued to rise in the HH game so that mean core temperature was about 0.5 °C higher by half time in the more challenging environment. Even though the players in the HH match covered insignificant but less distance in the first half, their body core temperature was significantly higher than that was measured in the MH match (Figs 1 and 2). Also, in the second half of the HH game in spite of the significantly less distance covered by the players, their T_c was higher than in the match played in MH-indexed environment (MH match). In both matches, players spent most of their time standing or walking and walking distance was significantly higher in HH match. Data from this study show that with the increased HI, the players' activities in the speed range of 7.5–19.5 km/h (jogging and low–moderate-speed running) were significantly reduced in the second half of the HH match. Sprinting and high-speed activities (speeds above 19.5 km/h) seem not to be affected by HH index.

These differing thermal responses may be partially accounted for by differences in activity patterns but it may equally be that differences in the activity patterns are the result of the players' decision to limit the amount of activity to prevent further rises in core temperature. During uncompensable heat stress, a steady-state core temperature cannot be achieved during exercise at a fixed power output, and hence body core temperature rises until exhaustion occurs at physiological limits (Sawka & Young, 2006). In a game such as football, the player has no control over the environment in which he is asked to play and has limited options in selecting the clothing that is worn. Fitness and heat acclimation status are determined before kick off and are therefore constants during the match, although they may change greatly over the course of a season. In addition, the work rate is determined to a large extent by the playing style of the team and of the opposing players. Where body temperature is rising rapidly, the player can choose intentionally or reflexively to reduce the rate of metabolic heat production by reducing the speed of running and by reducing the amount of time spent in high-intensity activities.

There is some evidence that hyperthermia may have a direct effect on brain function and that a high body temperature *per se* may contribute to fatigue during prolonged exercise in a hot environment. The brain has a high rate of metabolic heat production and Nybo et al. (2002) showed that even during exercise, the brain temperature is higher than the core (arterial) temperature. In addition, there appears to be a reduction in the ability to voluntarily activate muscles during sustained maximal contractions when body temperature is elevated (Nybo & Nielsen, 2001). These findings are consistent with the "central governor" model that prevents a failure of homeostasis by causing a voluntary cessation of effort – or a reduction in exercise intensity – when homeostasis is challenged (Noakes et al., 2005). Impellizzeri et al. (2004) showed that players perceptions of effort during training were closely correlated with various physiological measures made, indicating that conscious regulation of effort may be occurring. Tucker et al. (2006) suggested that the brain responds to high rates of heat storage by reducing the work rate so as to limit further rises in core temperature. This system is proposed to limit the rate of heat production during exercise, thus allowing a task to be completed before catastrophe (fatigue). Possible neurochemical mechanisms underpinning these responses have been described elsewhere (Maughan et al., 2007b).

The total distance covered during MH and HH matches was 8613 ± 584 and 8155 ± 731 m, respectively. In the previous studies, the average total distance covered was >10 km (Mohr et al., 2003; Krustrup et al., 2005; Di Salvo et al., 2007). The total distance covered is related to the level of competitive play, with higher distances covered in the top leagues (Reilly et al., 2008); hence, this may account at least in part for the difference. The total distance covered in both MH and HH matches were nearly 15–20% less than the moderate level players' soccer match data (Mohr et al., 2003). This difference can be explained with the level of competition and higher environmental temperature together with relative humidity. Owing to the timing of our study, thermal responses of the players in MH and HH matches were measured in a hot and humid environment and it would be worthwhile to study both thermal and performance responses of soccer players in a cool environment as well.

It is also well known that players at a high standard of competition perform significantly more high-intensity running than those at lower standards (Ekblom, 1986; Bangsbo et al., 1991). Ekblom (1986) calculated that the distance covered in high-intensity running during a match amounted to 500 m when the environmental temperature was 30 °C compared with 900 m when the temperature was 20 °C. This is consistent with the present findings. Generally, players cover 5–10% less distance in the second half of the game (Stølen et al., 2005; Reilly et al., 2008) though Di Salvo et al., (2007) reported no difference in distance covered in the two halves in top class players. In the present study, players covered 5% less distance in the second half of the MH match, whereas this difference was 15% and significant in the HH match, consistent with a greater level of fatigue (Fig. 2).

It is widely accepted that a loss of sweat equivalent to >2% of body mass has detrimental effects on performance. In our study, in both matches, players began the match in a dehydrated state (urine specific gravity values of MH and HH matches were 1.024 ± 0.007 and 1.030 ± 0.000, respectively) despite the efforts to ensure adequate fluid intake. The players' sweat rate and levels of dehydration were similar in the MH and HH matches, as reported elsewhere (Kurdak et al., 2010).

Perspectives

In soccer matches played in high environmental temperature and humidity, the physical performance of the players may decrease due to high thermal stress. In the present study, in soccer match played in higher ambient temperature and relative humidity, the players' increased body core temperature in the half time with a decrease in total distance covered in the second half of the game may point out centrally driven performance reduction. Where players can choose their pace, they may do so to keep the thermal strain within tolerable limits.

Key words: heat, fatigue, match analysis, hyperthermia.

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Conflicts of interest: The authors have no potential conflicts.

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