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Original Article

Hydration and sweating responses to hot-weather football competition

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During a football match played in warm (34.3 ± 0.6 °C), humid (64 ± 2% rh) conditions, 22 male players had their pre-match hydration status, body mass change, sweat loss and drinking behavior assessed. Pre-match urine specific gravity (1.012 ± 0.006) suggested that all but three players commenced the match euhydrated. Players lost 3.1 ± 0.6 L of sweat and 45 ± 9 mmol of sodium during the 90-min match and replaced 55 ± 19% of their sweat losses and hence by the end of the game were 2.2 ± 0.9% lighter. The water volume consumed during the game was highly variable (1653 ± 487 mL; 741–2387 mL) but there was a stronger relationship between the estimated pre-game hydration status and water volume consumed, than between sweat rate and water volume consumed. In a second match, with the same players 2 weeks later in 34.4 ± 0.6 °C, 65 ± 3% rh, 11 players had a sports drink available to them before and during the match in addition to water. Total drink volume consumed during the match was the same, but approximately half the volume was consumed as sports drink. The results indicate that substantial sweat water and electrolyte losses can occur during match play in hot conditions and a substantial water and sodium deficit can occur in many players even when water or sports drink is freely available.

Exercise in the heat adds thermal stress to the body and it typically responds by sweating in an attempt to control body temperature. This, however, has the potential to disrupt body water and electrolyte balance. It is known that substantial body temperature increases can occur during football match play (Rico-Sanz et al., 1996; Mohr et al., 2004; Edwards & Clark, 2006) and that significant sweat volume and electrolyte losses can occur in football players during training and match play (Maughan et al., 2004, 2005, 2007; Shirreffs et al., 2005; Shirreffs & Maughan, 2008). These losses can be highly variable between individuals even when performing the same exercise at the same time in the same conditions (Shirreffs et al., 2006). Also, at present, there are far more data available from training scenarios than from match situations and indeed there are currently no data in the scientific literature describing the sweating and body-temperature responses of football players playing competitive matches in a warm environment. This, therefore, was the aim of this present study.

Materials and methods

Data were collected before and during two of three competitive football matches played in the summer of 2008. Twenty-two players (age 20 ± 2 years, height 176 ± 2 cm, mass 68 ± 7 kg) played in the matches, which occurred outdoors, at the same time in the afternoon, in July in the southern Turkish city of Adana. The matches were FIFA-regulation 90-min matches. The environmental conditions during the matches are shown in Table 1. Before undertaking any data collection, ethics committee approval was obtained from Çukurova University and all subjects gave their written informed consent to participation.

Approximately 5 h before the start of the match, the players swallowed an ingestible temperature pill (VitalSense®, Mini Mitter Co. Inc., Bend, Oregon, USA). Subjects ate a standardized pre-match meal of sandwiches 3 h before the start of the matches. This meal was the same before both matches. On arrival at the match venue, approximately 45 min before the start of the match, players were asked to empty their bladder as fully as possible and keep a 20 mL sample in a container provided to them. The specific gravity of this sample was determined by refractometry (Atago, Tokyo, Japan) and was used to estimate the pre-match hydration status (Shirreffs, 2003; Sawka et al., 2007).

Over a 15-min period from 30 to 15 min before the start of the match, all players were weighed to the nearest 20 g on an electronic balance (Kurdaklar Scale, Adana, Turkey) when wearing only their underwear. Then during the first match only, immediately after being weighed, players were prepared for sweat sample collection as described previously (Maughan et al., 2007; Maughan & Shirreffs, 2008). Briefly, players had absorbent patches (Tegaderm+™ pad, 3M, Loughborough, UK) placed on four locations: their forearm, thigh, chest and back, all on the right side of their body. Before sticking the patches to the skin, the locations were washed thoroughly with deionized water and dried with electrolyte-free gauze. These patches remained in place for the warm-up and first half of the match. As soon as the referee stopped the match for the half-time break, players had patches removed with electrolyte-free forceps and each patch was placed in an electrolyte-free container, which was sealed immediately after the patch was placed within it.

Within the last 15 min before the game, players were fitted with a heart rate monitor combined with a global positional system receiver (Forerunner 305, Garmin, Southampton, UK) that were worn during the match, using the same methods and procedures as reported in an accompanying paper (Özgünen et al., 2010).

On completion of the 90-min matches, players were reweighed on the same balance as their pre-match mass was determined, again wearing only their underwear. This was completed within 15 min of the end of the match: players were not allowed to eat or drink until after they had been weighed.

During the first match, all players had access to drinking water. During the second match, one team (Team W) had access to drinking water only while the other team (Team SD) had access to both drinking water and a commercially available sports drink (Powerade, Coca Cola, Istanbul, Turkey). All bottles were individually numbered and players only drank from bottles assigned to them. During the first match, drinking was neither encouraged nor discouraged before and during the match and players were left to behave as they wished with regard to drinking. During the second match, the players who were provided with the sports drink in addition to water were informed that there were limitless quantities and they could drink freely and have as much as they wished. In both matches, sponges and non-drinking water were provided by the pitch side for players who wanted to pour water over themselves during the match. All drink bottles were weighed on electric scales (LS2000, Ohaus, Leicester, UK), measuring to the nearest 1 g, before and at the end of the match to determine the volume consumed by each player. A volume of 1 mL of water/sports drink was assumed to weigh 1 g for the purposes of this study.

Some players wanted to urinate after the first body mass measurement and before the second measurement were made. These players were allowed to do so but were asked to collect the entire volume in a container provided. The mass of this was determined on electric scales (LS2000, Ohaus) measuring to the nearest 1 g, assuming 1 mL of urine weighed 1 g, and the post-exercise body mass measurement was corrected to take this mass into account.

From the first match, the volume of sweat collected in each patch was determined gravimetrically on electric scales (AC100, Mettler, Zürich, Switzerland) measuring to the nearest 0.0001 g. The mass of the patch and container into which it was placed was determined previously and the sweat volume was determined by assuming 1 mL of sweat weighed 1 g when the storage tube and its contents were reweighed. The sweat collected was analyzed for sodium (Na^+) and potassium (K^+) concentrations by flame photometry (Corning, 410C, Sherwood Scientific, Cambridge, UK).

Statistical analysis

Data were tested for normality of distribution by the Kolmogrov–Smirnov and Shapiro–Wilk tests, for skewness and kurtosis by looking at the ratio of the mean of the relevant value to its standard error and for homogeneity of variance. Relationships between parameters were investigated by Pearson correlations. Comparisons between paired data were made using the paired *t*-test; comparisons between data from different subjects were by the unpaired *t*-test. All statistical analyses were performed using SPSS v 16. Data are presented as mean ± SD and, when of interest, the range of data is given in square parentheses.

Results

The pre-match urine specific gravity data (Table 2) indicated that players, on average, started the matches in a euhydrated condition (<1.020; Sawka et al., 2007). However, examination of the individual data indicated that three players in the first match and two different players in the second match presented with pre-match urine specific gravities >1.020, which may be indicative of a hypohydrated condition.

In all four game halves, the players of Team W always covered the same distance as the players in Team SD ($P>0.250$) averaging 4158 ± 386 m per half. In the first match, there was no difference in the distance covered in each of the two halves by either team ($P>0.09$) but in the second match, players in both teams covered a greater distance in the second half (4298 ± 363 m) than in the first half (3913 ± 284 m) ($P<0.013$).

The intestinal temperatures recorded before, during and at half time of each match are shown in Fig. 1. The temperature increased over the duration of the first half, then decreased over the half time break and the first part of the second half before increasing again over the second half of the match. The highest temperature recorded in the first match was at half time in one player of Team W and at the 35th minute of the second half in another player of Team W and was 40.6 °C in both cases. In the second match, the highest temperature recorded was 40.3 °C and this was recoded in two players of Team W at the 20th minute of the first half.

A summary of the data collected before, during and after each match is shown in Table 2. There was no difference in any of the measured parameters between the two teams in the first match ($P>0.437$).

Table 1. Environmental conditions of temperatures (°C) and relative humidity (%) during the matches

	Match 1	Match 2
Temperature (°C)	34.3 ± 0.6	34.4 ± 0.6
Relative humidity (%)	64 ± 2	65 ± 3
Heat index apparent temperature (°C)	45 ± 2	46 ± 2

Data are presented as mean ± SD.

Table 2. Body mass and body mass loss, drink, urine and sweat volumes, pre-match urine-specific gravity and (where collected) sweat sodium and potassium concentration and estimated losses

	Match 1		Match 2	
	Team W	Team SD	Team W	Team SD
Pre-match body mass (kg)	70.66 ± 7.41 [50.16–78.70]	65.91 ± 4.79 [59.70–73.50]	71.36 ± 8.40 [49.72–80.26]	66.52 ± 4.94 [60.10–73.78]
Post-match body mass (kg)	69.29 ± 7.01 [50.28–77.60]	64.26 ± 4.59 [57.62–70.58]	69.76 ± 7.94 [49.52–79.08]	64.80 ± 4.71 [58.62–71.70]
Body mass loss (kg)	1.37 ± 0.62 [gain of 0.12–1.96 loss]	1.65 ± 0.67 [0.20–2.92]	1.60 ± 0.66 [0.20–2.22]	1.71 ± 0.66 [0.04–2.52]
Body mass loss (%)	1.88 ± 0.89 [gain of 0.24–2.89 loss]	2.49 ± 0.94 [0.30–3.97]	2.19 ± 0.86 [0.40–3.04]	2.56 ± 0.93 [0.06–3.47]
Drink volume consumed (mL)	1832 ± 499 [741–2387]	1474 ± 423 [929–2203]	1521 ± 354 [1144–2282]	1347 ± 411 [738–2160]
Urine volume (mL)	69 ± 60 [0–159]	46 ± 50 [0–155]	43 ± 58 [0–162]	46 ± 54 [0–176]
Urine specific gravity	1.012 ± 0.006 [1.004–1.025]	1.010 ± 0.006 [1.003–1.022]	1.012 ± 0.008 [1.003–1.030]	1.006 ± 0.003 [1.003–1.014]
Number with urine-specific gravity greater > 1.020	2	1	2	0
Sweat volume (L)	3132 ± 603 [2159–3843]	3077 ± 545 [2403–3867]	3081 ± 833 [1477–4402]	3013 ± 551 [2200–3982]
Sweat sodium concentration (mmol/L)	43 ± 11 [27–59]	46 ± 8 [25–53]		
Sweat potassium concentration (mmol/L)	3.5 ± 0.5 [2.9–4.0]	3.5 ± 0.3 [3.2–3.9]		
Sweat sodium loss (mmol)	137 ± 50 [87–219]	140 ± 26 [97–189]		
Calculated sweat salt loss (g)	8.0 ± 2.9 [5.1–12.8]	8.2 ± 1.5 [5.6–11.0]		

Values are mean ± SD with the minimum and maximum values in square parentheses.

There were also no differences in any of the measured parameters between the two matches for Team W who had only water available to them before and during each match ($P > 0.284$). However, the pre-match urine specific gravity for Team SD was significantly lower before their second match than it was before the first match ($P = 0.030$) and it was also lower than that of Team W before the second match ($P = 0.007$).

In neither match was there a relationship between the pre-match urine specific gravity and the body mass loss over the course of the matches (Fig. 2), but there was a significant correlation between pre-match urine specific gravity and the drink volume consumed during the matches (Fig. 3). The relationship between sweat rate and drink volume consumed was not significant (Fig. 4).

In the second match, when 11 players in one team had both the sports drink and water available to them, they consumed the same volume (1347 ± 411 mL) as they had done in the first match (1474 ± 423 mL; $P = 0.294$) when only water was available to them. On average, they consumed equal amounts of water (0.8 ± 0.5 L) and sports drink (0.5 ± 0.3 L) during this match ($P = 0.197$). However, one individual (the goalkeeper) consumed only plain water during the match.

Discussion

The results of this study indicate that substantial sweat water and electrolyte losses can occur during match play in hot conditions. These sweat water and electrolyte losses are similar to those reported previously for elite professional players training in hot environments (Shirreffs et al., 2006); e.g. in 26 male professional players, training for 90 min when the environment was 32 ± 3 °C, 20 ± 5% rh and wet bulb globe temperature was 22 ± 2 °C, the estimated sweat volume lost was 2193 ± 365 mL (1672–3138 mL) (Shirreffs et al., 2005). Further, even though water was freely available to players during the first match, many players developed a significant degree of hypohydration. Indeed, 16 of the 22 players lost > 2% of their body weight over the course of the match and on average 55 ± 19% of the sweat volume losses were replaced by drinking over the course of the match. At the extremes, one player drank a volume of water greater than his sweat loss, consuming approximately 200 mL more than the estimated sweat volume, and one player drank almost 3 L less than his sweat loss. Fluid intake across both games ranged from 738 to 2387 mL, with a mean intake of 1544 mL. This is substantially higher than the mean (± SD) intake of 0.84 ± 0.47 L reported for players in a competitive game played in a cool environment (Maughan et al., 2007).

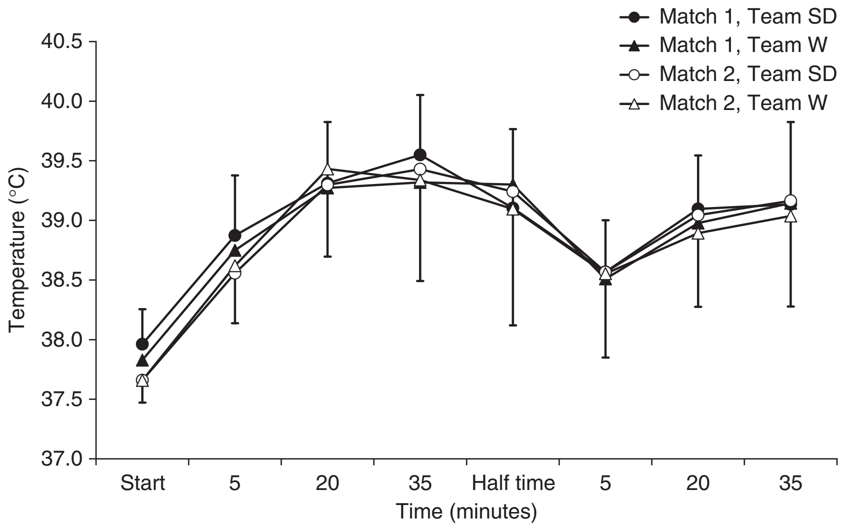

Fig. 1. Intestinal temperature (°C) before, during and at half time of the match. Values are mean ± SD.

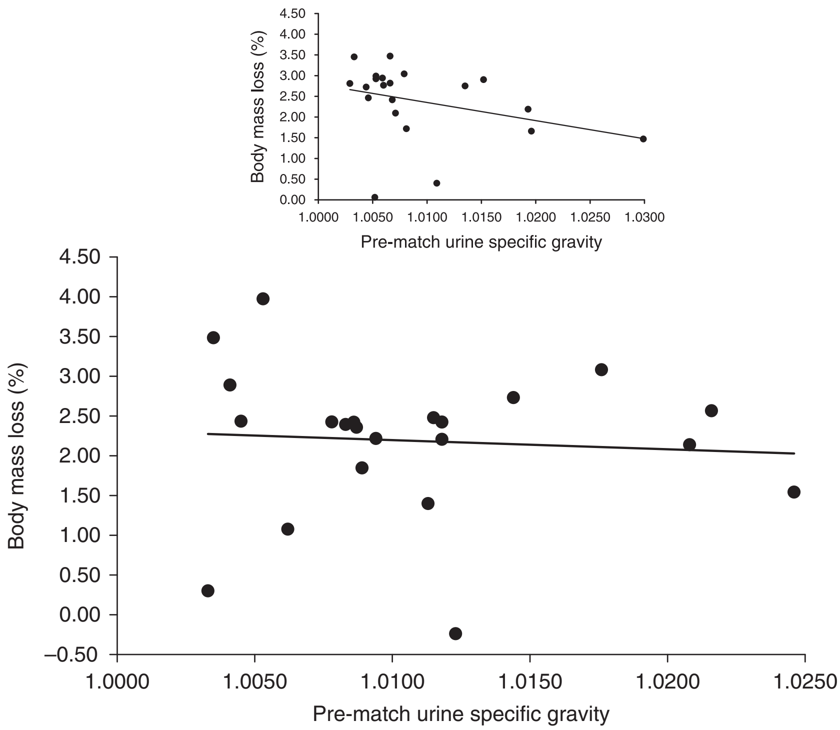

Fig. 2. Match 1 pre-match urine specific gravity and the body mass loss (%) over the course of the match. There is no significant relationship ($r^2 = 0.005$, $P = 0.749$). Data from match 2 are shown in the smaller figure.

In the second match, when the players in one team were given a sports drink and were encouraged to drink freely and as much as they desired, these players did produce a pre-match urine sample with a lower specific gravity and no players had a urine specific gravity >1.014, perhaps suggesting that they drank more in the lead up to this game than before the previous match. However, during the match, there was no change in the overall hydration outcome of these players. They consumed the same overall drink volume, sweated the same amount and thus completed the match with the same extent of body mass loss. These players were not accustomed to having sports drinks freely available in the lead up to the matches nor during their matches. The novelty factor may have been expected to cause them to consume more overall, but this did not materialize. This may have been because they were familiar with advice not to introduce new dietary practices before games, but this is only speculation.

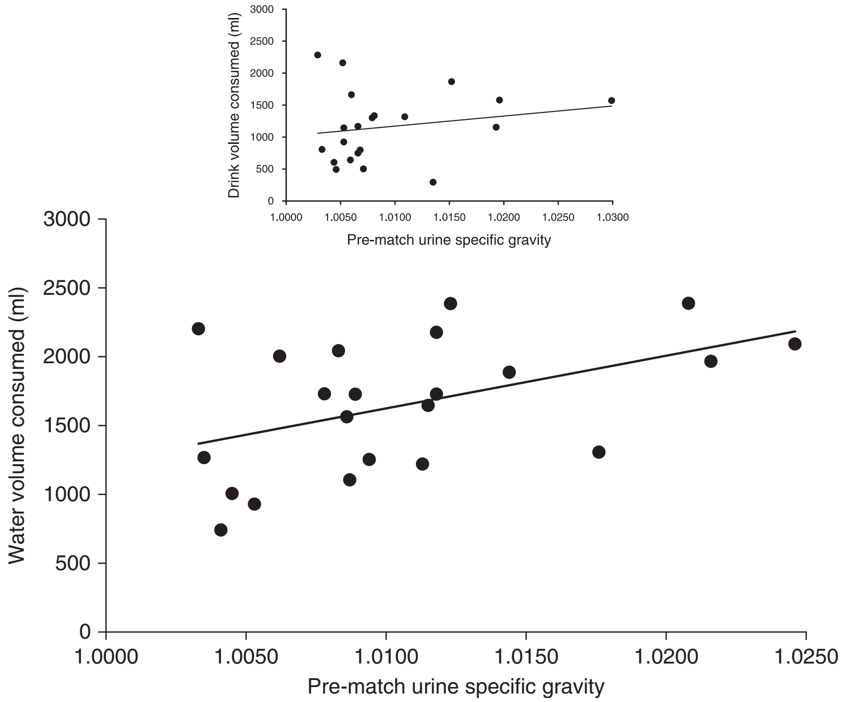

Fig. 3. Match 1 pre-match urine specific gravity and the drink volume consumed (mL) during the match. There is a significant relationship ($r^2 = 0.218$, $P = 0.028$). Data from match 2 are shown in the smaller figure.

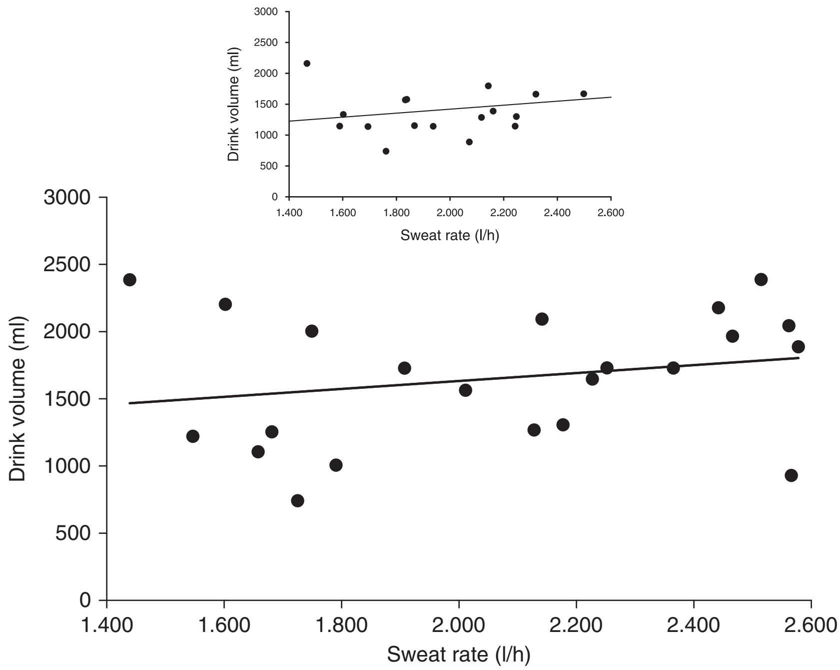

Fig. 4. Match 1 sweat rate (l/h) and the drink volume consumed (mL) during the match. There is no significant relationship ($r^2 = 0.051$, $P = 0.311$). Data from match 2 are shown in the smaller figure.

The data show a large elevation in core temperature during the game, with the highest values tending to be achieved toward the end of the first half of the game. This is similar to the response observed in similar conditions as reported in the companion paper (Özgünen et al., 2010). In that study, peak T_c was also recorded at about the 30th minute of the match, at values of 39.1 ± 0.4 °C for a match played at 34 ± 1 °C and 38 ± 2% relative humidity, and at 39.6 ± 0.3 °C for a match played at 36 ± 0 °C and

61 ± 1% rh. This contrasts with the data of Edwards and Clark (2006), who, also using an ingestible temperature sensor system, found that the highest temperatures were recorded at the end of games played in cooler conditions (16–19 °C). There may be limitations to the use of the ingestible temperature sensor system when cool water is ingested during exercise, as was the case in this study. Wilkinson et al. (2008) suggested that ingestion of a relatively large bolus (250 mL) of chilled water (5–8 °C) caused transient excursions of 2 °C or more of the measured temperature. Goodman et al. (2009) suggested that at least 5 h should elapse between ingestion of the temperature sensors and the start of the monitoring period. In the present study, this amount of time was allowed, but some individual values may have been affected by the temperature of the ingested drinks. The temperature values should perhaps therefore be considered to be an underestimate of the true value. The intestinal temperature of these players during each of these two matches was the same as was the distance that they covered. Hence, taking this information and the knowledge that the environmental conditions were the same for the two matches, it is perhaps not surprising that the sweating response was the same. Had the players' drinks been chilled, the body temperature rise may have been attenuated (Lee & Shirreffs, 2007; Lee et al., 2008a, b) and thus the sweating rate may have been reduced.

There is not a substantial body of data available on which to ascertain conclusively any influence of hypohydration on football performance. Indeed, it is probably not possible to assess the influence of hydration status on football performance; successful performance is ultimately a winning performance, which is influenced by physical, cognitive and other aspects, including tactics and other external influences. It is possible to investigate the influence of hydration status on some of the types of activities and processes that contribute to football performance, but even for this, there is limited information available on which to draw strong conclusions (Shirreffs, 2009). Endurance exercise is the type of performance for which there are the most reliable data available and the current evidence suggests that reductions in body mass in the order of 2–7% significantly reduce endurance exercise performance, particularly in environments that are warmer than 30 °C (Cheuvront et al., 2003). Football certainly has an endurance aspect with in the order of 10 km traveled by outfield players over the course of a 90-min match (Bangsbo et al., 2006). As the match reported here was played in warm conditions, it would be reasonable to surmise that the endurance aspect of these soccer players' performance would be negatively influenced. However, it is feasible that playing style was altered to account for this, thus reducing the endurance aspect or in other words, the distance covered by the players. Without studying these players in other situations, we do not know if this was the case. From studies that have investigated aspects of football performance (McGregor et al., 1999; Edwards et al., 2007), reductions in the ability to perform soccer-specific tests of dribbling and intermittent-type running/walking have been demonstrated in laboratory tests. McGregor et al. (1999) reported that fluid replacement with flavored water, sufficient to limit body mass loss to 1.4% prevented a reduction in soccer skill performance in comparison with a 5% deterioration in performance when body mass was reduced by 2.5%. Edwards et al. (2007) indicated that body mass reductions of approximately 2% resulted in a reduction in intermittent-type running/walking test performance in comparison with a trial when drinking resulted in a body mass reduction of only 0.7%.

It seems likely that all but three players were euhydrated when they started the first match and all but two started the second match euhydrated. Unlike data from a match played in cool conditions (Maughan et al., 2007), there was a significant relationship between the pre-match urine specific gravity and water volume consumed during the match. Similar measurements made on elite players training in a cool (5 °C) environment also showed a relationship between the pre-training hydration status, as assessed by urine osmolality, and the amount of fluid consumed during the session (Maughan et al., 2005). There was still a considerable variation in the volume consumed, but it is interesting to note the presence of this relationship in the absence of a significant relationship between sweat rate and drink volume. The rules and nature of football matches do have a significant impact on the opportunities players have to access drinks, but further research may usefully verify this finding and address the mechanisms that drive drinking behavior according to the physiological situation before exercise rather than that during exercise.

Perspectives

The results of this study indicate that football players can find themselves under considerable physiological stress if they play a match in warm or hot environmental conditions. Substantial sweat water and electrolyte losses can occur in this situation even when drinks are freely available to players in accordance with current FIFA rules.

Key words: hydration status, sweat loss, sweat composition.

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References

Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci 2006: 24: 665–674.

Cheuvront SN, Carter R III, Sawka MN. Fluid balance and endurance exercise performance. Curr Sports Med Rep 2003: 2: 202–208.

Edwards AM, Clark NA. Thermoregulatory observations in soccer match play: professional and recreational level applications using an intestinal pill system to measure core temperature. Br J Sports Med 2006: 40: 133–138.

Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP. Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. Br J Sports Med 2007: 41: 385–391.

Goodman AD, Kenefick RW, Cadarette BS, Cheuvront SN. Influence of sensor ingestion timing on consistency of temperature measures. Med Sci Sports Exerc 2009: 41: 597–602.

Lee JKW, Shirreffs SM. The influence of drink temperature on thermoregulatory responses during prolonged exercise in a moderate environment. J Sports Sci 2007: 25: 975–985.

Lee JKW, Shirreffs SM, Maughan RJ. The influence of serial feeding of drinks at different temperatures on thermoregulatory responses during cycling. J Sports Sci 2008a: 26: 583–590.

Lee JKW, Shirreffs SM, Maughan RJ. Cold drink ingestion improves exercise endurance capacity in the heat. Med Sci Sports Exerc 2008b: 40: 1637–1644.

Maughan RJ, Shirreffs SM. Assessing hydration status and making recommendations. Int J Sport Nutr Exerc Metab 2008: 18: 457–472.

Maughan RJ, Shirreffs SM, Merson SJ, Horswill CA. Fluid and electrolyte balance in elite male football (soccer) players training in a cool environment. J Sports Sci 2005: 23: 73–79.

Maughan RJ, Merson SJ, Broad NP, Shirreffs SM. Fluid and electrolyte intake and loss in elite soccer players during training. Int J Sports Nutr Exerc Metab 2004: 14: 333–346.

Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM. Water balance and salt losses in competitive football. Int J Sports Nutr Exerc Metab 2007: 17: 583–594.

McGregor SJ, Nicholas CW, Lakomy HKA, Williams C. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. J Sports Sci 1999: 17: 895–903.

Mohr M, Krustrup P, Nybo L, Nielsen JJ, Bangsbo J. Muscle temperature and sprint performance during soccer matches – beneficial effects of re-warm-up at half-time. Scand J Med Sci Sports 2004: 14: 156–162.

Özgünen KT, Kurdak SS, Maughan RJ, Zeren Ç, Korkmaz S, Yazıcı Z, Ersöz G, Shirreffs SM, Binnet MS, Dvorak J. Effect of extreme environmental conditions on physical activity patterns and thermoregulation of football (soccer) players. Scand J Med Sci Sports 2010: 20(Suppl. 3): 140–147.

Rico-Sanz J, Frontera WR, Rivera MA, Rivera-Brown A, Mole PA, Meredith CN. Effects of hyperhydration on total body water, temperature regulation and performance of elite young soccer players in a warm environment. Int J Sports Med 1996: 17: 85–91.

Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. Exercise and fluid replacement. Med Sci Sports Exerc 2007: 39: 377–390.

Shirreffs SM. Markers of hydration status. Eur J Clin Nutr 2003: 57(Suppl. 2): S6–S9.

Shirreffs SM. Hydration, fluids and performance. Proc Nutr Soc 2009: 68: 17–22.

Shirreffs SM, Aragon-Vargas LF, Chamorro M, Maughan RJ, Serratosa L, Zachwieja JJ. The sweating response of elite professional soccer players to training in the heat. Int J Sports Med 2005: 26: 90–95.

Shirreffs SM, Maughan RJ. Water and salt balance in young male football players in training during the holy month of Ramadan. J Sports Sci 2008: 26(Suppl. 3): S47–S54.

Shirreffs SM, Sawka MN, Stone M. Water and electrolyte needs for football training and match-play. J Sports Sci 2006: 24: 699–707.

Wilkinson DM, Carter JM, Richmond VL, Blacker AD, Rayson MP. The effect of cool water ingestion on gastrointestinal pill temperature. Med Sci Sports Exerc 2008: 40: 523–528.