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Evaluation of pre-game hydration status, heat stress, and fluid balance during professional soccer competition in the heat

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Abstract

This study evaluated initial hydration status (stadium arrival urine specific gravity), fluid balance (pre- and post-game nude body weight, fluid intake, urine collection), and core temperature changes (pre-game, half-time, post-game) during a professional soccer game. We monitored 17 male players (goalies included) between stadium arrival and game end (3h), playing at 34.9°C and 35.4% relative humidity, for an average Wet Bulb Globe Temperature (WBGT) heat stress index of 31.9°C. Data are mean ± SD (range). Initial urine specific gravity (USG) was 1.018 ± 0.008 (1.003-1.036); seven players showed USG ≥ 1.020. Over the three hours, body mass (BM) loss was 2.58 ± 0.88kg (1.08-4.17kg), a dehydration of 3.38 ± 1.11%BM (1.68-5.34%BM). Sweat loss was 4448 ± 1216mL (2950-6224mL), vs. fluid intake of 1948 ± 954mL (655-4288mL). Despite methodological problems with many players, core temperatures greater than or equal to 39.0°C were registered in four players by halftime, and in nine by game's end. Many of these players incurred significant dehydration during the game, compounded by initial hypohydration; thermoregulation may have been impaired to an extent we were unable to measure accurately. We suggest some new recommendations for soccer players training and competing in the heat to help them avoid substantial dehydration.

Keywords: *Nutrition, football, dehydration, thermoregulation*

Introduction

Several recent studies performed during team practices have shown that professional soccer players from some of the best teams in the world can incur dehydration levels similar to those observed in endurance sports. This can happen in the presence of good fluid availability and regular hydration breaks (Maughan, Merson, Broad, & Shirreffs, 2004; Maughan, Shirreffs, Merson, & Horswill, 2005; Shirreffs, Aragon-Vargas, Chamorro, Maughan, Serratosa, & Zachwieja, 2005). Therefore, dehydration may also be an issue in this stop-and-go team sport.

Sweat rates and dehydration levels may be influenced by the environmental conditions, but many other variables come into play, such as training intensity and clothing. Variations from player to player may be larger than those recorded under varying conditions. For instance, elite players training at 32.3 ± 3°C ambient temperature and 20 ± 5% relative humidity (r.h.), showed an average sweat rate of 1.46 ± 0.24 L/h (*M* ± *s*; range 1.12-2.09 L/h), and reached a dehydration level of 1.59 ± 0.61 % body mass (range 0.71-3.16%) (Shirreffs et al., 2005); another group of elite players training at 5.1 ± 0.7°C and 81 ± 6% r.h. showed an average sweat rate of 1.13 ± 0.30 L/h (range 0.71-1.77 L/h), with an unexpected dehydration level of 1.62 ± 0.55% (range 0.87-2.55%) (Maughan et al., 2005). While mild dehydration levels may not be particularly crucial when playing or training in cooler environments (Coyle, 2004), it is widely accepted that greater dehydration can impair physical performance and may even threaten the well-being of athletes when training or competing in the heat (Armstrong, Casa, Millard-Stafford, Moran, Pyne, & Roberts, 2007; Casa, Armstrong, Hillman, Montain, Reiff, Rich, et al., 2000; Coyle, 2004; Sawka & Pandolf, 1990; Sawka, Burke, Eichner, Maughan, Montain, & Stachenfeld, 2007).

Little information is available on dehydration and thermoregulation during actual games, especially in hot environments (Broad, Burke, Cox, Heeley, & Riley, 1996; Rico-Sanz, Frontera, Rivera, Rivera-Brown, Mole, & Meredith, 1996). Compared to training, dehydration would be expected to be considerably different during a soccer match because of the limited opportunities for drinking during the game. The situation can be made worse when home teams from hot and humid locations in the tropics schedule their games around noontime (when solar radiation and general environmental heat stress tend to be highest) in an attempt to take advantage of their level of heat acclimatization. This practice has been criticized because it subjects the public in the stadium to long, often unprotected exposure to ultraviolet rays (Moncada, 2003); however, the environmental heat stress may be having a negative impact on the players' performance as well. While assessing this impact on performance during actual soccer competition is not feasible, it is possible to measure some physiological responses during the game. It is also possible to compare the actual environmental conditions and challenges faced by the players with widely used recommendations for safe competition in the heat (Armstrong et al., 2007; Binkley, Beckett, Casa, Kleiner, & Plummer, 2002; Sawka et al., 2007).

The purpose of this descriptive study was to evaluate how professional soccer players cope with the demands of competition during heat stress and to compare players' responses and challenges with some existing recommendations for hydration and heat illness prevention during soccer games. More specifically, we attempted to assess initial hydration status and changes in hydration during the game, as well as monitoring core temperature changes, during a professional soccer game in the Costa Rica national league held near the Pacific coast.

Methods

Participants

The twenty-two starting players of a regular game of the professional first division soccer league in Costa Rica were identified the night before the game and selected for the study. The study was approved by the Human Subjects Research Committee from the University of Costa Rica. The study purpose and procedures were explained to the teams' technical and medical staff and to all players, and informed consent was obtained in advance from the players of both teams.

Procedures

Three hours before kickoff, during breakfast, participating players ingested a CorTemp™ disposable temperature sensor (HQ Inc., Palmetto, FL, USA). Upon arrival in the stadium, approximately one hour before the game, players were requested to empty their bladders and collect the urine in plastic containers. Players were then weighed nude to the nearest 20 grams, using a portable digital scale. From this point on, and until the post-game body weight measurement, they were instructed to drink at will but only from their own, individually labeled bottles. These bottles were weighed to the nearest 1 gram using digital food scales and labeled before being provided to the players. They were kept cold in portable coolers and handled by each team's staff under the supervision of a researcher. Both teams started their warm-up approximately 30 minutes before the game. At the end of the game or when substituted, players were weighed out nude after emptying their bladders. All the urine produced in between body weighings was collected and measured for volume. Once a participant finished playing, he was not allowed to drink anything else until he weighed out. At the end of the game, all bottles were collected and weighed out as well.

Environmental conditions were monitored every 15 min with a QuesTemp 36 thermal environment monitor (Quest Technologies, Oconomowoc, WI, USA). The monitor was placed on the playing field behind one of the goals, one meter above ground. The Wet Bulb Globe Temperature heat stress index (WBGT) was calculated as 0.7 Twb + 0.2 Tg + 0.1 Tdb, where Twb is the wet bulb temperature, Tg is the black globe temperature, and Tdb is the dry bulb temperature, according to the equation recommended by the American College of Sports Medicine (Armstrong et al., 2007), modified from Yaglou and Minard (1957). Initial hydration status of each player was assessed from his urine sample, using an Atago® urine specific gravity (USG) refractometer (Atago, Tokyo, Japan). USG ≥ 1.020 was defined as an indicator of hypohydration, as recommended by Bartok, Schoeller, Sullivan, Clark, and Landry (2004).

Each individual's core temperature was registered in triplicate before warm-up, at half-time, and at the end of the game. Four researchers manually recorded the body temperatures using a CorTemp™ CT-2000 recorder.

Fluid intake was calculated by subtracting the final bottle weight from the initial bottle weight; an estimation of fluid intake by counting the number of gulps and multiplying by 30 mL was also made with a few players, as one of the teams decided to use non-labeled bottles at some points during the game.

Individual dehydration incurred during the game was calculated as % of the pre-game body mass (%BM) using the difference between initial and final body mass. In these calculations and sweat loss calculations, mass changes due to metabolism and respiratory water loss were considered negligible (Maughan et al., 2004). Sweat losses were calculated from body mass changes, corrected by fluid intake and urinary loss during the time interval between weighing in and weighing out (about three hours total).

Statistical analysis

Statistical analyses were performed using SPSS version 10.1. Descriptive statistics included mean, standard deviation (SD), and minimum and maximum values (range). Variables were checked for normality. Teams were compared on each variable of interest by using Student's t-tests for independent samples, verifying equality of variances by Levene's test. A 95% confidence interval (95%CI) was calculated for the difference in the means for each variable. Finally, simple regression analyses were performed with fluid intake as the dependent variable and sweat loss or initial hydration status as predictors.

Results

Environmental conditions in or near the home city for each team for the 30 days preceding game day, as registered by the Costa Rican National Weather Service are presented in table 1, as a gross indication of the level of acclimatization of the teams; typical practice time was 9 a.m., 4 to 5 times a week. Most players do not dwell in air-conditioned homes; the visiting team arrived one day before the game and stayed in an air-conditioned hotel.

Table 1. Environmental conditions during the 30 days preceding game day, as an indicator of acclimatization potential. Ambient temperature is dry bulb temperature.

	Ambient temperature, *M* ± *s* (°C)			**Relative humidity, *M* ± *s* (%)**		
Time of day	9 a.m.	12 noon	3 p.m.	9 a.m.	12 noon	3 p.m.
Home	29.3 ± 0.7*	32.5 ± 0.9*	33.0 ± 1.2*	50.7 ± 4.4	40.4 ± 4.3*	39.3 ± 4.9*
Visitors	25.9 ± 0.9	28.6 ± 1.2	27.8 ± 1.7	51.4 ± 7.7	43.5 ± 5.3	47.0 ± 10.7

*p < 0.05 between Home and Visitors

The teams arrived at the stadium approximately 75 min before kickoff, which was scheduled at 11 a.m. Game time was close to 95 min. The average time between weighing in and weighing out was almost three hours (see below). Game day was sunny and hot as confirmed by the environmental conditions reported in Table 2. With only a few games left in the year's tournament, the teams arrived tied for third place. The first half finished 2-2; final score was 7-2, a win for the visitors.

Table 2. Environmental conditions on game day registered 10:30 a.m. to 12:45 p.m. (10 measures).

	Dry bulb T (°C)	Wet bulb T (°C)	Globe T (°C)	r.h. (%)	WBGT (°C)
M	34.9	26.6	48.8	35.4	31.9
S	1.2	0.7	2.8	4.2	1.2
Range	32.6 - 36.1	25.5 - 27.5	43.8 – 51.6	30.0 – 42.0	30.0 – 33.2

Two players from each team declined to participate in the study at the last minute. In addition, one subject declined to swallow the temperature sensor, although he participated in the rest of the measurements. Finally, one participating player was injured early in the first half of the game, bringing the total sample down to 16 players (17 for all analyses not including core temperatures).

Descriptive statistics for the entire group of 17 players are presented in table 3. Team comparisons showed that the home team had a higher initial USG than the visitors (1.022 and 1.014, respectively, $p = 0.026$). Sweat rates were not significantly different between teams (1.58 ± 0.36 vs. 1.39 ± 0.36 $L \cdot h^{-1}$, $p = 0.295$), even though the home team had a higher total sweat loss (5.09 ± 1.19 vs. 3.88 ± 0.97 L, $p = 0.036$)

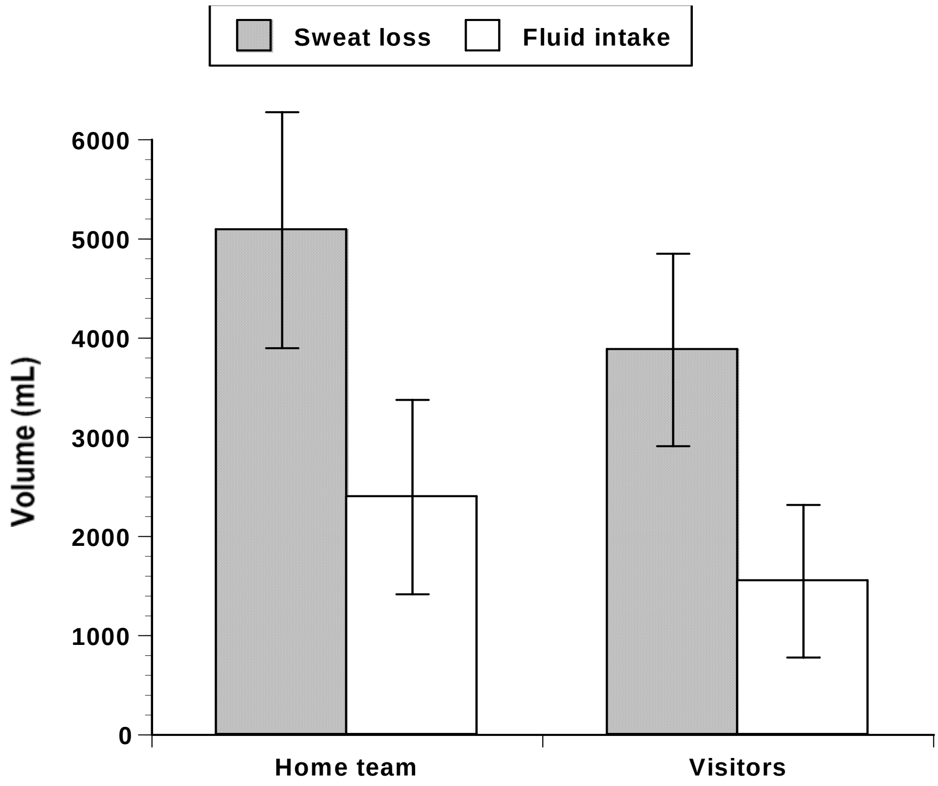
because their heat exposure time and hence time between measurements were higher (192.5 ± 7.1 vs. 167.5 ± 9.6 min, $p < 0.0005$).

Table 3. Overall descriptive statistics for variables of interest on game day (n = 17).

Variable	*M*	*s*	Range
Body mass (kg)	76.2	7.7	64.3-96.5
Initial urine specific gravity	1.018	0.008	1.003-1.036
Sweat loss (mL)	4448	1216	2950-6224
Sweat rate (mL/h)	1483	362	1034-2008
Total fluid intake (mL)	1948	954	655-4288
Total urine output (mL)	82	119	0-512
Dehydration (% BM)	3.4	1.1	1.7-5.3
% of sweat loss replaced	43.7	16.8	19.8-80.9

There were no significant differences between the teams in initial body mass (weight), total fluid intake, total urine output, or dehydration ($p > 0.19$). Both teams replaced less than half of their sweat losses (40.6 ± 19.9 vs. 47.0 ± 13.1%, $p = 0.45$) (Figure 1). The difference in total fluid intake approached significance; the home team players drank 2.40 ± 0.98 L compared to 1.55 ± 0.77 L for the visitors ($p = 0.065$, 95%CI: -0.06–1.76 L). The two goalies had sweat rates of 1.72 and 1.10 $L{\cdot}h^{-1}$, resulting in game dehydrations of 2.7 and 2.9%, respectively.

Figure 1. Fluid balance in professional soccer players (*n* = 17, *M* ± *s*).



Body core temperatures shortly before the game were not different between teams ($p = 0.37$), with an average value of 37.3 ± 0.6°C (range 35.4 to 37.8°C; only one player was below 37.0°C). At halftime and at the end of the game, core temperatures for several individuals were clearly wrong, with values as low as 31.4°C. It was clear that the ingestion of large volumes of cold fluids interfered with the core temperature readings; the temperature values were therefore discarded.

There was a significant positive correlation between the volume of sweat lost in and around the game and the volume of fluid consumed during the same period (R^2 = 0.44, $p = .004$) (Figure 2). There was also a positive correlation between initial hydration status as assessed by USG and total volume of fluid consumed during the measurement period (R^2 = 0.29, $p = .025$ (Figure 3).

Figure 2. Correlation between game sweat loss and the total fluid intake for the game (R^2 = 0.44, P = 0.004) (n = 17).

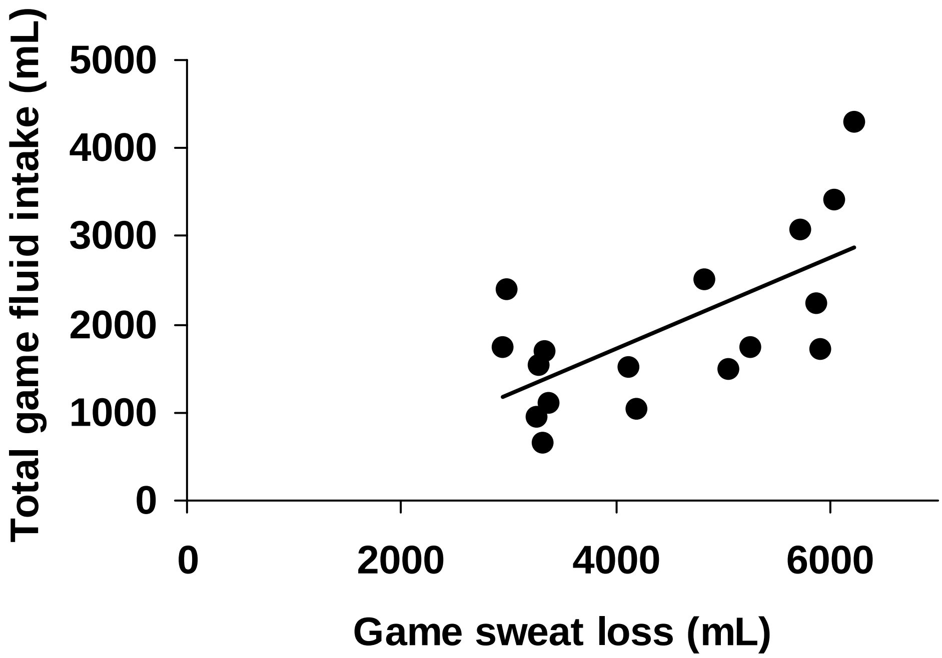
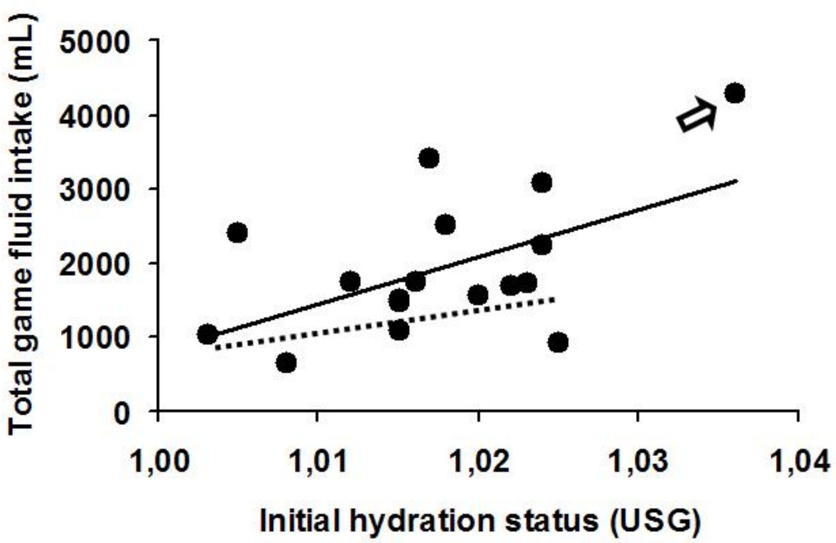


Figure 3. Correlation between initial hydration status and the total fluid intake for the game (r^2 = 0.29, P = 0.025) (n = 17). Dashed line is the regression line resulting from discarding the outlying player, indicated by the arrow (n= 16).



Discussion

The most important finding of this field study was the high level of dehydration (higher, to the best of our knowledge, than any reported for soccer competition or training), despite very high fluid intake. This experience also shows that it is possible to monitor sweat loss and fluid intake during a professional soccer game played in the heat. Measuring body temperature proved to be a more difficult challenge. However, we were able to detect a few important differences between teams even in a single game, with data collected on the field, such as initial hydration status and the consequences of time of exposure to environmental heat.

Our average fluid intake and sweat rate are very similar to those reported for professional European soccer players. Shirreffs et al. (2005) found an average sweat rate of 1460 mL • h^{-1} and a fluid intake of 650 mL • h^{-1} over 90 minutes of training in moderate heat (WBGT = 22.2°C). However, their players reached a much lower average dehydration of 1.59% BM. It is important to keep in mind that our monitoring time was close to three hours, including about one hour of no exercise. While it would be interesting to measure sweat loss and fluid intake during the actual playing time only, this is not feasible during professional soccer competition. The measurements we made represent the real-life situation and suggest that, when planning fluid intake for a soccer game to be played in a hot environment, it would be incorrect to simply apply individual typical sweat rates obtained during practice to the approximate 90-min duration of the game, as sweat losses before the game and during halftime may contribute significantly to dehydration.

Accuracy of the estimation of hydration status from body mass loss has been questioned because, in some exercise situations, a significant body mass loss may occur without an effective net negative fluid balance (Maughan, Shirreffs, & Leiper, 2007).

While the limitations of the method are real, the same authors accept body mass loss is the only realistic proxy measure of hypohydration for athletes and field studies. Most studies and available guidelines are based on numbers obtained with this method. Soccer studies reported and discussed in this paper have used the same methodology, and therefore our comparisons are valid. How close our measured body mass losses come to the effective water losses is beyond the scope of this paper.

Measurements were taken during a real professional tournament game, played under high WBGT values not common and yet possible in soccer competition or even training. No specific WBGT guidelines exist for football competition, but as a reference, the National Athletic Trainers Association (NATA) position statement on exertional heat illnesses (Binkley et al., 2002) considers WBGT values higher than 28°C as extremely risky, recommending rescheduling or delaying the event until safer conditions prevail, or being on high alert if the event must take place. Similarly, the American College of Sports Medicine position stand on exertional heat illness (Armstrong et al., 2007) recommends canceling continuous activity and competition when WBGT is ≥27.9°C, while stating that at WBGT ≥ 32.3°C even training and non-continuous activity should be cancelled because uncompensable heat stress exists for all athletes. WBGT was 32.4°C when this game started, and reached a high of 33.2 °C at the end of the game. While chronically acclimatized players would be expected to have better tolerance to high WBGT values, there are no evidence-based recommendations for WBGT limits for safe sports practice or competition in tropical climates.

There was a clear difference between teams regarding initial hydration status; five out of eight players tested from the home team arrived at the stadium with a USG ≥ 1.020, compared with only two out of nine tested players from the visitors. As mentioned above, this was associated with a significantly higher team average USG for the locals ($p < .05$). Initiating exercise already dehydrated can have clear negative consequences on performance, as shown by Armstrong, Costill, and Fink (1985). Recent studies have emphasized the desirability of starting soccer games euhydrated, because the opportunities for fluid intake during matches are limited, and also because gastric emptying and intestinal absorption of the ingested fluid may be compromised during the game (Maughan et al., 2004). Too many individuals in this game (41% of the sample) did not meet the euhydration goal upon arrival, and possibly should have been ingesting more fluid.

What happens in the time between stadium arrival and game start is also crucial. When competing or training in the heat, athletes are advised to stay in the shade or in cool areas as long as they can, to minimize sweat losses and heat gain when not actively engaged in the game or practice. In many hot locations, locker rooms and most of the facilities in the stadium are not air conditioned. Game dehydration is aggravated by considerable sweating during warm-up before the game and even standing still or sitting in a hot locker room before the game or at half-time. Time of heat exposure can make an important difference, as shown in the results above: sweat rates were similar between teams, but a longer time of exposure for the home team resulted in losing about one more liter of sweat between the time they walked into the locker room, and the end of the game. In this particular case, the visitors reduced heat exposure by staying at the hotel with air conditioning as late as possible, and traveling to the stadium in an air-conditioned bus, while the home team arrived earlier at the stadium, mostly from homes with no air conditioning.

Athletes have been advised to avoid dehydration during training and competition, by drinking to match individual sweat losses (Aragón-Vargas et al., 1999; Aragón-Vargas, 2004). It has been recognized that this is sometimes not possible due to high sweat rates (Coyle, 2004), which may exceed by far the individual's maximum capacity for gastric emptying. More recently, the guideline is to avoid excessive dehydration (greater than 2% BM, Sawka et al., 2007), but even this might be a challenge when sweat rates are high and exposure to heat is long. The intermittent effort typical of soccer competition, combining periods of low intensity with short bursts of high intensity, has been shown to slow gastric emptying, placing an even lower limit on fluid intake capacity (Leiper, Broad, & Maughan, 2001; Leiper, Prentice, Wrightson, & Maughan, 2001). How close can soccer players come to matching their sweat losses in the heat? It has been argued before that during soccer competition, due to limited opportunities for drinking, fluid intake is naturally low relative to sweat loss. But even during training in the heat, without the limitations of game rules, average fluid intake has been reported at about 970 mL in 90 min, or about 647 mL/h, replacing on average only 47% of sweat loss (Maughan et al., 2004; Shirreffs et al., 2005). The soccer players in the present game were much better drinkers than expected. Little fluid can be ingested during the actual game, leaving about 85 min for drinking most of the volume (1948 mL), a significant amount that is in reality much higher than the rate of about 650 mL/h if calculated conservatively over the three hours of monitoring. Given the environmental conditions of the game, it was not possible for the players to come close to their sweat losses (only 44% of sweat loss was replaced), resulting in undesirably high dehydration. According to Coyle (2004), average dehydration at the end of the game may have been high enough (3.38% BM) to have a negative impact on performance. The fact that many players were already hypohydrated upon arrival and weigh-in, when baseline body weight was obtained, means that, their actual dehydration at the end of the game was greater than reported here.

The combination of dehydration and exercise resulted in a small average urine collection, despite substantial fluid intake: many players could not produce any urine at all, and the average was only 82.3 mL of urine in about three hours, which is considerably less than the average obligatory urine loss of 1 mL per minute (Valtin & Schafer, 1995). It may not be realistic, however, to recommend that these players should drink more, unless they are given more opportunities to drink during the game.

Several recent studies highlight the importance of individual differences in both sweat losses and fluid intake, recommending an individualized hydration strategy (Maughan et al., 2004; Shirreffs et al., 2005). This is especially important in soccer competition, where some players may perform a lower amount of work than others, generating smaller amounts of heat during the game because of their position, game strategy, or playing style. Our data show that goalies can lose considerable amounts of sweat, and therefore need to pay attention to hydration too. We confirmed important differences in sweat rates and even higher differences in fluid intake during this game. We could also identify five players who replaced less than 30% of their sweat loss, together with four players (not necessarily the same ones) who drank about one liter or less of fluid over the time of monitoring. These players could clearly improve their drinking. At the other extreme, none of the players we monitored drank too much, and they were all short of matching their sweat losses by at least 20%. This is different from long-distance events such as marathon running, where slow runners competing in cooler conditions may drink in excess of their sweat loss and be at risk of dilutional hyponatremia (Montain, Sawka, & Wenger, 2001). The best advice remains to assess individual sweat rates by monitoring weight changes during training and competition, in order to plan an individualized hydration strategy for each player to prevent excessive dehydration (Sawka et al., 2007).

Core temperatures obtained in this study were not correct. The technology we used has been validated properly (Lee, Williams, & Fortney-Schneider, 2000). All the sensors used were factory-calibrated and provided reasonable values until the players started ingesting large amounts of cold fluids. During pilot testing, we successfully measured core temperatures on 22 players during a friendly game in somewhat milder conditions (average WBGT=24.3°C), but fluid intake was lower (average of 1096 mL in two hours of monitoring). In both studies, temperature pills were ingested 3 hours before the start of the game. According to the manufacturers, 4 to 6 hours may be necessary for the sensor to pass into the small intestine, avoiding an effect of ingested fluid on temperature readings (H. Q. Inc., n.d.). In their technical report to NASA, Lee, Williams, and Schneider (2005), recommend a six-hour wait from the time of ingestion, for stable measurements. Our post-game measurements, almost five hours after pill ingestion, were still incorrect. Wilkinson, Carter, Richmond, Blacker, and Rayson (2008) reported that in some subjects, ingestion of 250 mL of cold water can lower the temperature reading using these capsules by as much as 6 °C, as late as 8 hours after ingesting the capsule, apparently due to the position of the capsule near the stomach, even if far along the small or even the large intestine. Under these real-life conditions of soccer competition, there was no control over either the timing or volume of fluid ingestion. Accurate body temperature monitoring of soccer players during competition in the heat remains a challenge.

Unlike the studies by Maughan et al. during soccer training (2004, 2005), there was a significant correlation between individual sweat loss and fluid intake during this game. While a causal relationship cannot be established from the present study, we suggest these players may have had a clearer perception of their fluid replacement needs; it is also possible that a higher fluid intake in some individuals enabled higher sweat rates than those of individuals who drank less. We also found a significant correlation between initial USG and fluid intake during the game: the tendency was for those who were more hypohydrated upon arrival to drink more during the game. This agrees with previously reported data on players training in the cold (Maughan et al., 2005). In our study, the relationship is strongly influenced by an outlier. Without that subject, the correlation drops to non-significance ($r^2 = 0.07$, $p = 0.31$). We feel that the player should be included as there is no reason to believe his data are incorrect. These results warrant further investigation.

To summarize**,** these professional soccer players suffered considerable dehydration, sweating profusely not only during the game, but also during warm-up, at halftime, and other non-game times. Drinking fluids intently was not enough to avoid an average 3.38% BM dehydration, an undesirable level when competing at an average WBGT = 31.9°C; unfortunately, we were unable to accurately measure the associated body core temperatures. The fluid balance problem was compounded by the fact that several players were already likely hypohydrated upon arrival. To cope with these challenges, players should pay attention to proper hydration before the game. They should avoid heat exposure as much as possible in the hours before the game, and have an individualized hydration protocol which considers all sweat losses, not only those during actual match play. Finally, when environmental heat stress is high, referees could facilitate more drinking opportunities during the game.

References

Aragón-Vargas, L. F., Maughan, R. J., Rivera-Brown, A., Meyer, F., Murray, R., de Barros, T. L., et al. (1999). [Physical activity in the heat: thermoregulation and hydration in Latin America]. Actividad física en el calor: termorregulación e hidratación en América Latina. In Biosystem Servicio Educativo (Ed.), [Proceedings of the 7th Symposium in Exercise Sciences] *Resúmenes del VII Simposio de Actualización en Ciencias del Ejercicio* (pp. 222-230). Rosario, Argentina: Biosystem Servicio Educativo.

Aragón-Vargas, L. F. (2004). [Hydration in soccer]. Hidratação no futebol. In T. L. Barros & I. Guerra (Eds.), [Science of Soccer] *Cięncia do futebol* (pp. 85-99). São Paulo, Brasil: Editora Manole Ltda.
Armstrong, L.E., Costill, D. L., & Fink, W. J. (1985). Influence of diuretic-induced dehydration on competitive running performance. *Medicine & Science in Sports & Exercise, 17,* 456-461.
Armstrong, L. E., Casa, D. J., Millard-Stafford, M., Moran, D. S., Pyne, S. W., & Roberts, W. O. (2007). American College of Sports Medicine position stand. Exertional heat illness during training and competition. *Medicine & Science in Sports & Exercise, 39*, 556-572.
Bartok, C., Schoeller, D. A., Sullivan, J. C., Clark, R. R., & Landry, G. L. (2004). Hydration testing in collegiate wrestlers undergoing hypertonic dehydration. *Medicine & Science in Sports & Exercise, 36,* 510-517.
Binkley, H. M., Beckett, J., Casa, D. J., Kleiner, D. M., & Plummer, P. E. (2002). National Athletic Trainers' Association position statement: Exertional heat illnesses. *Journal of Athletic Training, 37,* 329-343.
Broad, E. M., Burke, L. M., Cox, G. R., Heeley, P., & Riley, M. (1996). Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. *International Journal of Sports Nutrition, 6,* 307-320.
Casa, D. J., Armstrong, L. E., Hillman, S. K., Montain, S. J., Reiff, R.V., Rich, B. S. E., et al. (2000). National Athletic Trainers´ Association position statement: Fluid replacement for athletes. *Journal of Athletic Training,* 35, 212-224.
Coyle, E. F. (2004). Fluid and fuel intake during exercise. *Journal of Sports Sciences, 22,* 39-55.
Gonzalez-Alonso, J., Calbet, J. A., & Nielsen, B. (1999). Metabolic and thermodynamic responses to dehydration-induced reductions in muscle blood flow in exercising humans. *Journal of Physiology, 520,* 577-589.
Gonzalez-Alonso, J., Teller, C., Andersen, S. L., Jensen, F. B., Hyldig, T., & Nielsen, B. (1999). Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *Journal of Applied Physiology, 86,* 1032-1039.
H. Q. Inc. (n.d.). *CoreTemp Data Recorder user's guide*. Page 24.
Lee, S. M., Williams, W. J., & Fortney-Schneider, S. M. (2000). Core temperature measurement during supine exercise: esophageal, rectal, and intestinal temperatures. *Aviation, Space & Environmental Medicine, 71,* 939-945.
Lee, S. M. C., Williams, J.W., & Schneider, S. M. (2005). Core temperature measurement during submaximal exercise: Esophageal, rectal, and intestinal temperatures. Retrieved April, 2000, from http://ston.jsc.nasa.gov/collections/TRS/listfiles.cgi?DOC=TP-2000-210133
Leiper, J. B., Broad, N. P., & Maughan, R. J. (2001). Effect of intermittent high-intensity exercise on gastric emptying in man. *Medicine & Science in Sports & Exercise, 33,* 1270-1278.
Leiper, J. B., Prentice, A. S., Wrightson, C., & Maughan, R. J. (2001). Gastric emptying of a carbohydrate-electrolyte drink during a soccer match. *Medicine & Science in Sports & Exercise, 33,* 1932-1938.
Maughan, R. J., Merson, S. J., Broad, N. P., & Shirreffs, S. M. (2004). Fluid and electrolyte intake and loss in elite soccer players during training. *International Journal of Sports Nutrition and Exercise Metabolism, 14,* 333-346.
Maughan, R. J., Shirreffs, S. M., Merson, S. M., & Horswill, C. A. (2005). Fluid and electrolyte balance in elite male football (soccer) players training in a cool environment. *Journal of Sports Sciences, 23,* 73-79.

Maughan, R. J., Shirreffs, S. M., & Leiper, J. B. (2007). Errors in the estimation of hydration status from changes in body mass. *Journal of Sports Sciences, 25,* 797-804.

Moncada, J. (2003). [Ultraviolet radiation and the athlete's skin]. La radiación ultravioleta y la piel del deportista. *Revista Educación, 27,* 165-172.

Montain, S. J., Sawka, M. N., & Wenger, C. B. (2001). Hyponatremia associated with exercise: Risk factors and pathogenesis. *Exercise & Sport Sciences Review, 29,* 113-117.

Nybo, L., & Nielsen, B. (2001). Hyperthermia and central fatigue during prolonged exercise in humans. *Journal of Applied Physiology, 91,* 1055-1060.

Rico-Sanz, J., Frontera, W., Rivera, M., Rivera-Brown, A., Mole, P., & Meredith, C. (1996). Effects of hyperhydration on total body water, temperature regulation and performance of elite young soccer players in a warm climate. *International Journal of Sports Medicine, 17,* 85-91.

Sawka, M. N., & Pandolf, K. B. (1990). Effects of body water loss on physiological function and exercise performance. In C. V. Gisolfi, & D. R. Lamb (Eds.), *Perspectives in exercise science and sports medicine: Fluid homeostasis during exercise* (pp. 1-38). Carmel, IN: Brown & Benchmark.

Sawka, M. N., Burke, L. M., Eichner, E. R., Maughan, R. J., Montain, S. J., & Stachenfeld, N. S. (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. *Medicine & Science in Sports & Exercise, 39*, 377-390.

Shirreffs, S. M., Aragon-Vargas, L. F., Chamorro, M., Maughan, R. J., Serratosa, L., & Zachwieja, J. J. (2005). The sweating response of elite professional soccer players to training in the heat. *International Journal of Sports Medicine,* 26, 90-95.

Valtin, H., & Schafer, J. A. (1995). *Renal Function*. (3rd Ed.). Boston, MA: Little, Brown & Company.

Wilkinson, D. M., Carter, J. M., Richmond, V. L., Blacker, S. D., & Rayson, M. P. (2008). The effect of cool water ingestion on gastrointestinal pill temperature. *Medicine and Science in Sports and Exercise, 40*, 523-528.

Yaglou, C. P., & Minard, D. (1957). Control of heat casualties at military training centers. *A.M.A. Archives of Industrial Health, 16,* 302-316.

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