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FOOTBALL TASK FORCE

HYDRATION SCIENCE AND STRATEGIES IN FOOTBALL

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KEY POINTS

- Dehydration of >2% body mass deficit has been shown to impair football-specific performance, including intermittent high-intensity sprinting and dribbling skills. Dehydration is prevalent in football players, especially when training or match play takes place in a hot environment.
- Football players often start practice/match play in a dehydrated state, as indicated by measurements of urine specific gravity.
- In football, the opportunity for fluid intake during match play is rare; therefore, an effective hydration strategy is required.

INTRODUCTION

Football is a team sport characterized by repeated bouts of short duration high-intensity sprints in an endurance context that also requires the maintenance of skills throughout the match. The match duration is 90 min plus overtime (as needed) and split into two 45-min halves with a 15-min pause between halves (i.e., halftime) (Kirkendall, 2000). The distance run by a football player during a regular match ranges from ~8 to 13 km. The variability in distance is due to several factors including players' fitness level, playing position, level of play, tactics employed and weather conditions (Da Silva et al., 2012; Duffield et al., 2012; Maughan et al., 2007; Mohr et al., 2012). The estimated average energy expenditure of football players during a regular match is 16 kcal/min, corresponding to an oxygen consumption (VO_2) of ~75% of maximum for the average player (Bangsbo et al., 2006; Bangsbo, 2014). These high work rates are associated with a high level of metabolic heat production, as ~75-80% of energy is converted to heat in the working muscles (Shirreffs et al., 2005). At high ambient temperatures (i.e., greater than skin temperature, which is ~33°C at rest and up to ~36°C during exercise) heat is gained from the environment, adding to the body's heat load. During exercise, the primary mechanism by which heat is lost from the body is evaporation of sweat from the skin surface. Although this is an essential mechanism to control body core temperature, it leads to sweating-induced dehydration (Maughan et al., 2007). Dehydration is the process of body water loss and is often described in terms of changes in body mass during acute exercise. For example, 2% dehydration is defined as a water deficit equal to 2% of body mass. While thermoregulatory sweating is the primary source of body mass loss during acute exercise, there are other contributing factors; including losses of water vapor and carbon dioxide (produced via substrate oxidation) through expired air. In addition, body water gain occurs through metabolic water production and dissociation of water from glycogen. While the relatively small body mass changes due to respiration and metabolism can be estimated, for practical purposes, in most studies it is typically assumed that 1 kg of body mass loss represents ~1 L of water loss. For more discussion on the topic of hydration assessment methodologies the reader is referred to other Sports Science Exchange articles (Stachenfeld, 2013) and reviews (Maughan et al., 2007; Sawka et al., 2007).

Fluid ingestion is clearly the only way to replace sweat losses and thereby reduce the magnitude of dehydration. In football, the window of opportunity for fluid intake is limited to halftime or an unscheduled break throughout the match, for example, an injured player receiving medical assistance. Interestingly, since the allocation of the World Cup tournament to warm weather climates, such as Brazil 2014 and Qatar 2022, the governing body of Association Football's (FIFA) has altered regulations concerning opportunities for players to drink. Specifically, two additional "cooling breaks" (~1 min 30 s in duration) are offered to the player after 30 min of the first and second halves, when the wet bulb globe temperatures exceed 31°C (FIFA website). Therefore, players should work together with the team's nutritionist to develop a suitable hydration strategy to capitalize on these opportunities and avoid significant dehydration, especially when playing in hot climates.

The goals of this review are to 1) provide an overview of the effect of dehydration on football performance, 2) discuss the current hydration practices of football players in order to determine the most common hydration issues that need to be addressed and 3) recommend practical hydration strategies that can be implemented by coaches and trainers to ensure players are well hydrated before, during and after practices/matches.

EFFECT OF DEHYDRATION ON FOOTBALL PERFORMANCE

Football performance is dependent upon many facets of physical function including endurance, strength, power and sport-specific skill. Dehydration can have a negative impact on endurance performance, especially when dehydration is combined with heat stress. Although some individuals may be more or less sensitive to dehydration, the level needed to induce performance degradations approximates >2% decrease in body mass (Sawka et al., 2007). Muscle strength and anaerobic performance are less likely to be affected by dehydration (Ali & Williams, 2013; Cheuvront & Kenefick, 2014). Some authors argue that reductions in body mass (i.e., dehydration) during a weight-bearing activity, such as football, might be advantageous to force production and vertical jump height (Viitasalo et al., 1987). However, there is no evidence to support this notion. For example, in one study, a diuretic-induced reduction in body mass by 2.5% had no effect on sprint and power performance (Watson et al., 2005). Likewise, there was no correlation between the reduction in body mass and vertical jump height (Watson et al., 2005), suggesting that dehydration provides no advantage for weight-bearing activities like football.

McGregor et al. (1999) were the first to test the effects of dehydration on football-specific performance. In this study, ratings of perceived exertion (RPE) were higher toward the end of the 90-min Loughborough Shuttle Running Test (LIST) (13-20°C, 57% relative humidity) when no fluid was given to the players (resulting in 2.5% dehydration) compared to when fluid was provided (resulting in 1.4% dehydration) (Figure 1, panel A). Likewise, 2.5% dehydration slowed sprint time at the end of LIST in comparison to 1.4% dehydration (Figure 1, panel B). This study also showed that football-specific skill performance (i.e., dribbling skill) decreased by 5% from pre- to post-LIST with 2.5% dehydration, but was maintained with 1.4% dehydration. Altogether, the results of this experiment suggested that dehydration of 2.5% body mass deficit increases RPE and impairs sprinting and football dribbling skills toward the end of 90-min intermittent high-intensity exercise. However, 2.5% dehydration had no impact on football players' mental concentration test scores at the end of LIST.

Figure 1

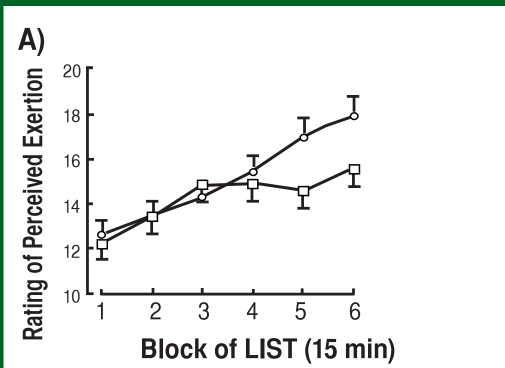
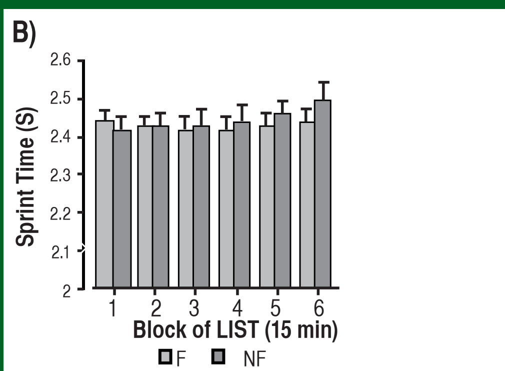


Figure 1. A) Ratings of perceived exertion (Borg scale) during each 15 min block of LIST. F= fluid trial ( ), NF = no fluid trial ( ). **P < 0.01 NF vs. F. B) Mean Spring time(s) during each 15 min block of the LIST. *P < 0.05 vs. F. Adapted from McGregor et al., J Sports Sci. 17, 895-903; 1999.



In another study, Edwards et al. (2007) demonstrated that post-match (90-min; 21-24°C, 55% relative humidity) performance of the Yo-Yo Intermittent Recovery Test (YYRT) was impaired when no fluid was given to the players (leading to 2.4% dehydration) compared to when fluid was provided (leading to 0.7% dehydration). Interestingly, another one of the experimental trials was a mouth rinse protocol where players washed their mouths with plain water in a volume corresponding to 2 ml/kg body mass, without swallowing the fluid. Mouth rinse resulted in 2.1% dehydration, which also reduced the total distance run by the football players during the YYRT. In addition, RPE was significantly higher in the no-fluid condition in comparison to mouth rinse and fluid intake trials. Another interesting aspect of this study was that in the fluid intake trial players drank an amount of fluid corresponding to 80% of their pre-estimated fluid loss, replaced at time points replicating match play opportunities for rehydration. This protocol resulted in a body mass loss of only 0.7%, thus representing a potential strategy to avoid significant dehydration in football players.

Most recently, Owen et al. (2013) examined the effect of dehydration on football skills (i.e., passing and shooting) and intermittent high-intensity running performance after the 90-minute LIST protocol in a temperate environment (19°C, 59% relative humidity). Despite differences in fluid intake (no fluid, *ad libitum* and prescribed volume) and dehydration (2.5%, 1.1% and 0.3%, respectively), football skills and intermittent high-intensity exercise performance were similar after the LIST. These results are in disagreement with previous research demonstrating that dehydration negatively affects football sprinting and skill performance (Edwards et al., 2007; McGregor et al., 1999). Explanations for the contradictory results might be related to the type of performance test employed. The skill performance test in McGregor et al. (1999) consisted of dribbling a ball through cones, whereas in Owen et al. (2013) the test involved shooting and passing a ball. However, it is difficult to draw firm conclusions from only three football-specific studies. Additional research is needed to clarify the effects of dehydration on the various aspects of football performance.

In a study in which *ad libitum* fluid intake was allowed, the total distance covered and number of high intensity running bouts in football players were significantly reduced when the match was performed in the heat (43°C, 15% relative humidity) in comparison to a control condition (21°C, 55% relative humidity); with a more pronounced reduction in the second half (Mohr et al., 2012). In this study, sweating rate was higher when the match was performed in the heat (4.1 ± 0.1 L/h) than when it was performed in the temperate condition (2.6 ± 0.1 L/h). However, players drank more fluid when the match was performed in hot weather (2.6 ± 0.2 L) than in temperate weather (1.1 ± 0.1 L), resulting in a similar degree of dehydration between conditions (hot = 1.9%; temperate = 1.8%). Thus, this study showed the negative effects of heat stress on football performance when hydration status was matched. More work is needed to better understand the combined effects of dehydration and heat stress on football performance.

Cardiovascular strain may be an important mechanism by which dehydration and/or heat stress compromise performance in football. Since total blood volume is decreased by dehydration, less blood and oxygen may be available to the active skeletal muscle and to the skin to support thermoregulation. Other mechanisms might involve altered central nervous system function, altered metabolic function or a combination thereof. The exact mechanism(s) by which dehydration impairs performance, particularly that of sports-specific skill, is currently unknown. The reader is referred to reviews by Cheuvront et al. (2010) and Cheuvront & Kenefick (2014) for a more detailed discussion on potential mechanisms.

FLUID BALANCE: CURRENT HYDRATION PRACTICES IN FOOTBALL PLAYERS

Body fluid balance is primarily a function of an individual's fluid intake (i.e., hydration practices) relative to his or her fluid losses (i.e., sweat) during practice or competition. Electrolytes, particularly sodium, are also lost with sweat. Electrolyte replacement is linked with hydration because replacing sodium losses increases the retention of ingested fluid (Shirreffs & Sawka, 2011). Prior to 2009, the literature on fluid and electrolyte balance in football players was relatively limited. This was partly because of the problems associated with obtaining accurate on-field data, but even more so to the reluctance of coaches to allow anything that might distract players from their immediate concerns with the outcome of the match (Maughan et al., 2007). Lately however, there has been an increasing number of studies published about fluid and electrolyte balance in both male (Duffield et al., 2012; Shirreffs et al., 2005; Williams & Blackwell, 2012;) and female (Gibson et al., 2012; Kilding et al., 2009) football players and even in referees (Da Silva et al., 2011; Da Silva & Fernandez, 2003).

Studies have reported sweat and electrolyte losses during training practices (Duffield et al., 2012; Gibson et al., 2012; Kilding et al., 2009; Shirreffs et al., 2005; Williams & Blackwell, 2012) or matches (Da Silva et al., 2012; Maughan et al., 2007). Usually, the methodology includes the collection of a pre-match/practice urine sample to determine urine specific gravity (USG) or urine osmolality followed by the recording of pre-exercise body mass. In studies where sweat electrolyte composition is determined, absorbent sweat patches are attached to various anatomical sites after the skin is thoroughly cleaned with deionized water and dried. Thereafter, bottles containing fluid (e.g., sports drink and/or plain water) identified with players' names are weighed before the given practice or match. Players are instructed to drink only from their personal bottles and not to spit any of the fluid out and not to rinse their faces with the water. They are also instructed to urinate in a container if needed during the practice/match-play so that this mass loss can be taken into account for sweating rate calculations. After the activity, sweat patches are removed and the body is toweled dry before post-match/practice body mass is recorded. Finally, bottles are re-weighed so the volume consumed during the training session or match can be calculated and taken into account for sweating rate calculations. This method is used to determine sweating rate, *ad libitum* fluid intake and percent change in body mass (i.e., fluid balance) and helps to identify those players with high sweat sodium losses who may need to pay particular attention to sodium replacement (Shirreffs et al., 2006).

Male Players

Dehydration is common occurrence in football players (Aragón-Vargas et al., 2009; Arnaoutis et al., 2013; Da Silva et al., 2012). For instance, Arnaoutis et al. (2013) assessed hydration status of 107 young football players (age 13 ± 2 years, range 11-16 years) during a training camp in the heat (27-29°C, 54-61% relative humidity). Based on first morning urine samples, 89% of the players were dehydrated (USG > 1.020 g/ml). After the practice, 96% of the players were dehydrated based on USG despite the fact that they had full access to fluids. In another study, male football players began a match in a dehydrated state (USG > 1.020 g/ml) and finished with an average post-match (35°C, 35% relative humidity) level of dehydration of 3.4% (Aragón-Vargas et al., 2009). Similar findings were observed before an official match in youth Brazilian football players (Da Silva et al., 2012). As shown in Table 1, the magnitude of dehydration appears to be influenced by the environmental conditions, as dehydration levels tend to be higher in hot climates and lower in temperate/cold weather. However, it is likely that other factors also contribute to the rate of sweat loss and the magnitude of dehydration, such as exercise intensity and even clothing (Aragón-Vargas et al., 2009). Yet other factors such as hydration knowledge/education likely impact fluid intake and the occurrence of dehydration in football players. In our experience, professional football players usually do not pay attention to their hydration habits on a daily basis. One study observed that while young football players were generally aware of the importance of hydration, they failed to translate this knowledge into successful hydration strategies (Decher et al., 2008).

Sweat losses in football players have been reported by several studies (Da Silva et al., 2012; Duffield et al., 2012; Maughan et al., 2007; Mohr et al., 2012). Maughan et al. (2007) described sweat losses in football players during actual match play at temperatures of 6-8°C. Despite the cold environmental temperature, sweat losses varied from 820 ml up to 2270 ml after 90-min of the match. In addition to demonstrating that sweat loss is highly variable among players, it is possible to conclude that a significant amount of fluid can be lost through sweating even when the match is played in the cold weather.

More recently, Da Silva et al. (2012) assessed fluid losses and fluid intake of elite Brazilian youth players during official match play. They reported no relationship between the total volume of sweat lost during the match and the volume of fluid ingested. This result indicates that those who sweat more do not necessarily drink more fluid *ad* *libitum*, which reinforces the need for an individualized hydration plan to avoid significant dehydration. Another interesting finding in this study was that players consumed fluid to replace only ~50% of their sweat losses resulting in 1.6 ± 0.7% dehydration (see Table 1). Other studies have reported that football players only replace about ~50% of fluid lost during training and competition (Aragón-Vargas et al., 2009; Shirreffs et al., 2006) indicating that relying on thirst may not be enough to prevent significant dehydration (see Figure 2).

Figure 2

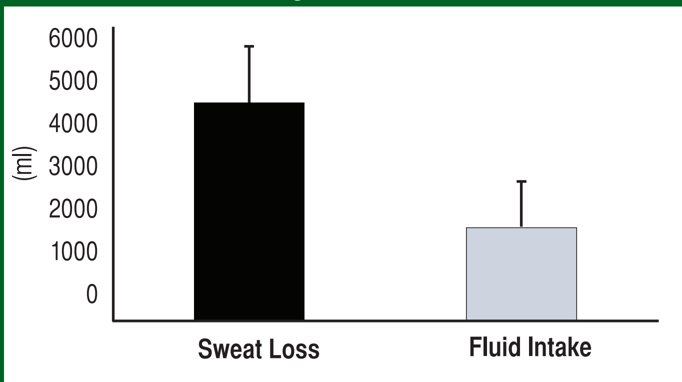


Figure 2. Fluid balance in professional soccer players (mean ± SD; n = 17) resulting in 3.4% dehydration. Adapted from Aragón-Vargas et al., *Eur. J. Sports. Sci. 9(5):269-276; 2009.*

Female Players

There is an increasing number of female football players across the world. However, the information about sweat and electrolyte balance in female football players is limited to a few studies during training; no data are available during actual match play (Gibson et al., 2012; Kilding et al., 2009). One study compared the response of female football players in two different training sessions on two separate days (Kilding et al., 2009). Results are reported in Table 1. In summary, sweating rate and electrolyte losses were small during football-specific training in cool conditions. More recently, another study measured fluid and sodium balance in elite junior women's football players during a practice in a cool environment (Gibson et al., 2012). Results from this study are also summarized in Table 1. An interesting finding of this study was that 45% of the 34 female football players presented to practice in a dehydrated state (USG > 1.020 g/ml). However, sweating rates and sodium losses during training were low, corroborating the Kilding et al. (2009) study. Although these results are in agreement with early studies suggesting that women have lower sweat and electrolyte losses than men (Bar-Or, 1998), more studies, particularly in the heat and during actual match play, are warranted.

Referees

One referee and two assistants (linesmen) supervise a football match. The distance covered by a referee during a match varies from ~9 to 11 km and average heart rate is ~165 beats/min (Catterall et al., 1993; Johnston et al., 1994). Consequently, the physical demand imposed on a referee is nearly as much as that observed in elite football players. It is therefore reasonable to speculate that referees are at as much risk of developing sweat-induced dehydration as football players. Very few studies have been performed with referees and linesmen. Da Silva and Fernandez (2003) measured six referees and six assistants during six different matches performed in a temperate environment (20 ± 1°C, 77 ± 4 % relative humidity). Referees lost 1.2 ± 0.1 kg, corresponding to 1.6 ± 0.1% of their pre-match body mass. Assistant referees lost 0.5 ± 0.1 kg of their body mass, corresponding to 0.6 ± 0.2% of their pre-match body mass. An interesting finding was that referees experienced a significant ~4% decrease in plasma volume, whereas assistants had a non-significant increase of 2.5%. While dehydration might have influenced the greater reduction in plasma volume observed in referees, it is likely that the assumed greater distance run by referees in comparison to the assistants could exacerbate the reported changes in plasma volume.

In another study, the same group of researchers investigated the effect of changes in the hydration status on the referees' performance (Da Silva et al., 2011). Ten referees were assessed during three official matches (23 ± 1°C, 67 ± 4% relative humidity). In one match, participants were asked to consume mineral water *ad libitum* while in the other matches they consumed a prescribed volume of mineral water or a carbohydrate-electrolyte solution corresponding to 1% of their baseline body mass (0.5% before the match and 0.5% during halftime). When drinking mineral water *ad libitum*, referees incurred 2.0 ± 0.2% dehydration. The body mass deficit was significantly attenuated to 1.3 ± 0.2% dehydration when referees drank the prescribed volume of mineral water and to 1.0 ± 0.2% when consuming the prescribed volume of carbohydrate-electrolyte drink. A time motion recording system was used to determine total distance run as well as distance covered by walking, jogging, running, sprinting and backwards running. Consumption of the carbohydrate-electrolyte solution was associated with less time spent in lower-speed activities (i.e., jogging) and more time spent in the more intense activities (i.e., backwards running). However, minimal differences in activity were found between *ad libitum* (2.0% dehydration) and prescribed (1.3% dehydration) mineral water trials. These results indicate that the implementation of a hydration strategy as opposed to *ad libitum* drinking in football referees may help prevent significant dehydration (i.e., >2% body mass deficit). However, more work is needed to determine the effect of dehydration on referee activity levels as well as other aspects of refereeing a football match, such as alertness and decision-making.

TABLE 1. Observations of sweat losses, voluntary fluid intake and levels of dehydration.

Study	n/Level of Player/Sex	Type of Activity, Duration /Environment	Sweat Loss (ml)	Fluid Intake (ml)	Dehydration (% BML)
Aragón-Vargas et al. 2009	17 professionals Male	Official match, 90 min / 35 ± 1°C, RH = 35 ± 4	4448 ± 1216	1948 ± 954	3.4 ± 1.1
Da Silva & Fernandez, 2003	6 referees and 6 assistants Male	Match-play, 90 min / 20 ± 1°C, RH = 77 ± 4%	Referees: 1600 ± 130 Assistants: 790 ± 190	Referees: 320 ± 60 Assistants: 250 ± 90	Referees: 1.6 ± 0.1 Assistants: 0.6 ± 0.2
Da Silva et al. 2011	10 referees Male	Match-play, 90 min/ 23 ± 1°C, RH = 67 ± 4 %	2140 ± 190	480 ± 90	2.0 ± 0.2
Da Silva et al. 2012	15 professional youth Male	Official match, 90 min / 31 ± 2°C, RH = 48 ± 5%	2240 ± 630	1120 ± 390	1.6 ± 0.8
Duffield et al. 2012	13 professionals Male	Game simulation 100 min / 27 ± 0.1, RH = 65 ± 7%	2600 ± 600	1166 ± 333	3.4 ± 0.7
Gibson et al. 2012	34 professional youth Female	Training practice, 90 min / 10 ± 3°C, RH = 63 ± 12%	690 ± 430	200 ± 20	0.8 ± 0.7
Kilding et al. 2009	13 professionals Female	Two football training practices, 90 min each / T1: 14 ± 1°C, RH = 71 ± 3%; T2: 6 ± 1°C, RH = 74 ± 3%	T1: 730 ± 270 T2: 660 ± 270	T1: 450 ± 250 T2: 379 ± 142	T1: 0.6 ± 0.5 T2: 0.5 ± 0.5
Maughan et al. 2007	20 professionals Male	Friendly match, 90 min / 6-8°C, RH = 50-60%	1680 ± 400	840 ± 470	1.1 ± 0.6
Shirreffs et al. 2005	26 professionals Male	Training practice, 90 min / 32 ± 3°C, RH 20 ± 5%	2193 ± 365	972 ± 335	1.6 ± 0.6
Williams & Blackwell, 2012	21 professional youth Male	Training practice, 100 min / 11 ± 1°C, RH = 50 ± 3%	1167 ± 662	807 ± 557	0.5 ± 0.5

Values are mean ± standard deviation. BML = body mass loss, RH = relative humidity, T1 = Training practice 1, T2 = Training practice 2.

Post-Exercise Rehydration

Rehydration is an important part of the post-exercise recovery process. If players have accrued a body mass deficit, they should aim to completely replace fluid and electrolyte losses prior to the start of the next training session or match. If dehydration is severe (>5% of body mass) or rapid rehydration is needed (e.g., < 24 h before next practice or match) the recommendation is to drink ~1.5 L of fluid for each 1 kg of body mass deficit (Shirreffs & Sawka, 2011). In most other situations, water and sodium can be consumed with normal eating and drinking practices with no urgency. Drinking a beverage with sodium or eating sodium-containing snacks/foods helps replace sweat sodium losses, stimulate thirst and retain the ingested fluids (Shirreffs & Sawka, 2011).

SUMMARY

Dehydration of >2% body mass deficit has been shown to impair football-specific performance, including intermittent high-intensity sprinting and dribbling skills. Football players and referees typically only consume enough fluid to replace ~50% of fluid losses during training and match play, which can result in ≥2% dehydration, especially in warmer environmental conditions. Additionally, it is often observed that football players start a practice or match play already in a dehydrated state, probably as a result of cumulative dehydration from previous training practices. Therefore, fluid intake on a daily basis may be as important as fluid intake strategies during competition.

PRACTICAL STRATEGIES

Education about the importance of fluid ingestion to football players' performance is fundamental and should start in the early stages of their career.

Use the urine color chart before training and match play to identify players who are dehydrated. Clear to light yellow (lemonade) indicates a well hydrated state. Consider using urine specific gravity (USG) as well. USG greater than 1.020 g/ml indicates dehydration. Track changes in body mass during training and match play in different environmental conditions to determine individual sweating rates and hydration habits. This will help identify players who are at risk of significant dehydration.

Individualize the hydration strategy based on players' sweating rate and drink preferences (e.g., beverage type and flavor to promote voluntary fluid intake).

Players should drink enough fluid during training/match play to prevent >2% dehydration. One strategy to achieve this goal in football is to encourage players to drink during any breaks in play.

Overdrinking relative to sweat losses should also be avoided.

Consider implementing hydration strategies for the football referees, as they may also incur significant dehydration during matches.

After exercise, if dehydration is severe (>5% of body mass) or rapid rehydration is needed (e.g., < 24 h before next practice or match) drink ~1.5 L of fluid for each 1 kg of body mass deficit.

Consuming a beverage with sodium or sodium-containing snacks/ foods helps replace sweat sodium losses, stimulate thirst and retain the ingested fluids.

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