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Review

Hydration: Special issues for playing football in warm and hot environments

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The high metabolic rates and body temperatures sustained by football players during training and matches causes sweating – particularly when in warm or hot environments. There is limited published data on the effects of this sweat loss on football performance. The limited information available, together with knowledge of the effects of sweat loss in other sports with skill components as well as endurance and sprint components, suggests that the effects of sweating will be similar as in these other activities. Therefore, the generalization that, on average, a body mass reduction equivalent to 2% should be the acceptable limit of sweat losses seems reasonable. This magnitude and more, of sweat loss is a common occurrence for some players. Sodium is the main electrolyte lost in sweat but there is large variability in sodium losses between players. However, the extent of sodium losses in some players may be such that its replacement is warranted for these players. Although football is a team sport, the great individual variability in sweat and electrolyte losses of players in the same training session or match dictates that individual monitoring to determine individual water and electrolyte requirements should be an essential part of a player's nutrition strategy.

The governing body of Association Football (or soccer), the Fédération Internationale de Football Association (FIFA) calculated in 2006 that a total of 270 000 000 people, or in other words, 4% or the world's population are actively involved in the game of football (FIFA, 2009a). This is made up of approximately 265 000 000 players (male and female) and 5 000 000 referees and officials. The data were collected by its 207 member associations, located in six of the seven world continents with only Antarctica not represented. Games of football are played in each of these six continents which provides wide and varied environmental conditions for the matches. While the Laws of the Game (FIFA, 2009b) allow for some flexibility with regards to game duration, clothing and equipment to be worn many players will find themselves playing in environments that are difficult in which to exercise. When considering hydration issues, it is hot environments that generate most cause for concern.

Body temperature when playing football

The amount and intensity of exercise performed by players during training or matches is such that body temperature increases even if the environment is cold (Mohr et al., 2004). Data collected both by rectal thermometer and ingestible temperature pill from players playing football matches in warm and hot conditions have suggested that body temperature may increased on average by around 2 °C or to around 39.5 °C (Rico-Sanz et al., 1996; Edwards & Clark, 2006; Özgünen et al., 2010). However, it should be remembered that these are average values from groups of players and some individual players will have temperatures significantly higher and lower than this.

Sweat water and electrolyte losses in football in the heat

Methods of assessing losses

It is common practice to use body mass changes as an index of body water content changes and thus of hydration status changes (Maughan et al., 2007a).

A wide range of values for all of the major electrolytes found in sweat has been reported in the literature, reflecting variations between individuals, differences due to the experimental conditions, and differences due to the collection methods. This last factor may be due to errors caused by contamination or to incomplete collection of the sample, or it may reflect a real difference induced by the collection site (e.g., arm vs chest, etc.).

The majority of published data from football players has been obtained using absorbent patches to collect sweat. While this is not a particularly difficult technique, clubs and players wanting to investigate their sweat electrolyte losses are likely to need specialized help to do so (Burke, 2005). Besides providing approximate sweat electrolyte losses, this approach, at a minimum, identifies those athletes with electrolyte rich (salty) sweat and who need to pay particular attention to electrolyte replacement. When it is not possible to determine electrolyte losses in this way, it may be possible to subjectively identify players with very high salt losses. That is, they may complain of the very salty taste of sweat in their mouth or that they have eye irritation when salt gets in their eyes or salt stains may be visible on clothing worn during training or matches.

Quantities lost

In recent years there have been several published papers reporting the results of "in-the-field" hydration monitoring, sweat collection and subsequent estimation of sweat electrolyte losses in football players during training and match-play (Maughan et al., 2004, 2005, 2007b; Shirreffs et al., 2005, 2006; Shirreffs & Maughan, 2008; Kurdak et al., 2010). Typically the following methodology has been used: Players are weighed nude or wearing only underpants before and after each training session or match. Between these two weighing periods, all urine excreted is collected and weighed and all drink consumed is accounted for by weighing drinks bottles. If solid food is consumed, the appropriate correction is applied to the player's body mass. Sweat losses are estimated by correcting the change in body mass for drinks consumed and urine passed. After appropriate cleaning of the skin, four absorbent patches are applied to the right side of the player's body on the forearm, thigh, upper back and chest. These are removed during or at the end of the training session or match for subsequent analysis. Attempts are made to make as few changes as possible to the players' normal procedures at each club. This ensures that data collected represent the player's normal behavior as closely as possible. The environmental conditions (e.g. wet bulb, dry bulb, globe temperatures, relativity humidity) in which the training sessions or matches take place is also recorded.

Water balance

The average calculated sweat losses, fluid intake and percent change in body mass for the players have typically been in the order of 1.5 L/h, 0.7 L/h and 1.5%, respectively. However, the mean values detract from the considerable variation in both sweating response and drinking behavior among players. As shown in Fig. 1, there is a substantial variation in responses and behavior between players. This variation however seems not to be due to the difference in body size between players (Shirreffs et al., 2006) so other factors like activity rate, heat acclimatization status and genetic differences probably contribute to this large variability.

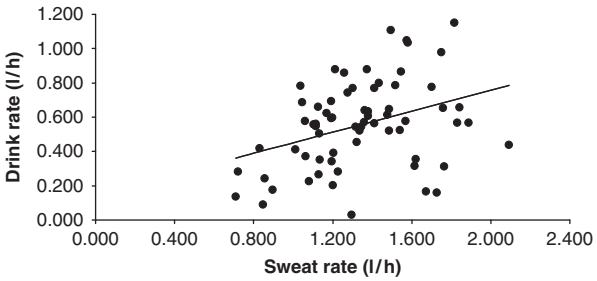

Fig. 1. The significant relationship between sweat rate and drinking rate. Each symbol represents a different players.

It is possible to gain an estimate of hydration status before exercise using a measure of urine concentration (Shirreffs & Maughan, 1998; Sawka et al., 2007). In many studies in this area, this type of assessment has been done and the results suggest that while it may not be the norm for players to start training sessions or matches hypohydrated, a significant minority of players do.

Electrolyte balance

The main electrolyte lost in sweat is sodium, with chloride being present in slightly lesser amounts. However, there are other electrolytes present (e.g., potassium, calcium, magnesium) although in vastly lower concentrations (Lentner, 1981; Shirreffs & Maughan, 1997). For the purpose of this review, only sodium will be considered in detail: sodium is the electrolyte that is lost in largest quantities in sweat and has the most physiological impact in terms of the conditions it leaves behind i.e. influencing plasma osmolality. It is also the electrolyte that has been demonstrated to be essential for replacement after exercise along with water, for post-exercise rehydration.

The average sweat sodium concentration measured in players at each of the clubs was typically in the range of 40–50 mmol/L but once again the mean values detract from the considerable variation in sweat sodium concentration and sodium losses between players as illustrated in Fig. 2 showing calculated sweat salt losses during 90 min training sessions. It is, of course, important to remember that these data have been determined from localized collection of sweat from four sites on the body. From the limited evidence available, this procedure may

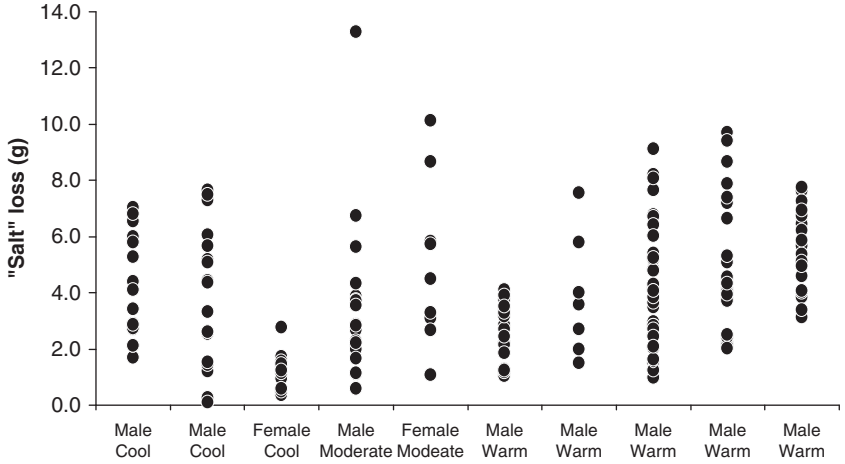

Fig. 2. Calculated sweat salt losses during 90 min training sessions. Each column of data represents players at the same football club being tested at the same time in the environments described in the *x*-axis. Each symbol represents a different player.

lead to overestimating the actual whole-body sweat sodium losses by approximately 30–40% (Shirreffs & Maughan, 1997; Patterson et al., 2000; Baker et al., 2009) but it is one of only a few methods that can be used in the field in typical training and match play situations.

Current practice and practical recommendations for football players training and playing in the heat

Water requirements

There are limited published data on the effects of a body water deficit on performance in football (McGregor et al., 1999; Edwards et al., 2007), and there is no information on top-level players. However, it unlikely that, on average, any negative effects would be seen until hypohydration reaches at least a level equivalent to a 2% loss of body mass (Cheuvront et al., 2003), and perhaps even greater losses could be tolerated in cool environments (Cheuvront et al. 2005).

From the data collected from football players, it is apparent that many players match their drinking sufficiently close to their sweat losses to restrict their body mass losses to less than a 2% body mass reduction, but this is certainly not always the case (Maughan et al., 2004, 2005, 2007b; Shirreffs et al., 2005, 2006; Shirreffs & Maughan, 2008; Kurdak et al., 2010). Indeed some players, because of their high sweat rates and/or because the gastric emptying rate of carbohydrate-electrolyte containing sports drinks may be slowed by the intermittent-type activity of football games and training (Leiper et al., 2001), raising the possibility that feelings of stomach fullness may limit the volumes players can comfortably consume, may not be able to drink a volume that would keep body mass losses at these levels. Whether on not these are the reasons for the higher body mass losses reported in the literature is unknown, but when these players are identified, it would be feasible to investigate and identify the reason or reasons for the occurrence. Then, depending upon what these are, acceptance of current practices or identification of new practices such as changing drink composition may be warranted. Some further practical recommendations have been previously suggested (Shirreffs et al., 2004, 2006) and are given in Table 1.

Electrolyte requirements

As described above, there is substantial variation in sweat sodium losses during football training and match play. It seems as if the majority of the players have sodium losses of <3–4 g during a training session or match and as such it is not likely to be essential that these losses are replaced during the training session or match (Coyle, 2004). But for a small minority of players some consideration must be given to consuming drinks containing sodium during the training sessions and matches.

Conclusions

From knowledge of the effects of water and electrolyte loss on athletes undertaking other forms of activity and sport, it seems prudent to recommend that football players training and or playing in the heat consider the benefits of limiting their body mass loss due to water loss during both training sessions and matches to less that about 2%. However, the activity pattern in football may make this recommendation difficult for some players in many situations, in which case careful consideration must be given to providing drinks that are palatable, encourage drinking and reduce the likelihood of slowing gastric emptying.

Table 1. Some practical recommendations to establish water and electrolyte needs in football and some practical recommendations regarding water and electrolyte consumption

Monitoring fluid/electrolyte status in players
Treat each player is as an individual
Measure body mass changes during training and matches
Educate players on their likely individual sweat losses during training and matches
If feasible, monitor each player individually (in varying environmental conditions) in training and in match-play to assess electrolyte losses
Or identify salty sweaters by taste, eye irritation, salt stains on clothing to identify possible problem players
Water and electrolyte intake
Ensure adequate hydration prior to/during training or matches
Drink approximately 500 mL or the equivalent of 6–8 mL per kilogram of body mass (e.g. water, sports drink, other soft drink) 2 h before the start.
Consume plain water at this time only if some solid food is consumed with it; this will provide electrolytes and in particular sodium to retain the consumed water
When appropriate, ensure each player has suitable drinks available during training and matches
During training and matches, limit body mass loss (due to sweat loss) to about 2% of body mass, if possible
When drinking is deemed necessary, choose a drink with a composition that has a minimal slowing effect on gastric emptying rate
During training and matches, consume a drink containing some sodium if significant amounts (3–4 g) are likely to be lost
When the environmental conditions are such that large sweat losses are likely in some or most players, consider specific drink break opportunities during each half of the match
At half time provide salted snacks with beverages
Use active post-match rehydration when speed, efficiency and effectiveness of rehydration is a priority
Body cooling
Consider core cooling if body temperature rise is a concern
Match officials
Consider as players

During matches and training sessions some players will lose considerable quantities of electrolytes – particularly sodium – and may need to replace these during the match or training session. If sodium-containing beverages do not suffice, athletes may want to consume small amounts of salted snacks between periods to replace salt losses and stimulate drinking.

Finally, the inter-individual variation between players in the same team taking part in the same training session or match is so great that players must be treated as individuals with regard to their water and electrolyte needs.

Key words: water balance, electrolyte balance, sweating, hydration, soccer.

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