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Time motion analysis of football (soccer) referees during official matches in relation to the type of fluid consumed

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Abstract

The aim of the present study was to determine the effect of volume and composition of fluid replacement on the physical performance of male football referees. Ten referees were evaluated during three official matches. In one match the participants were asked to consume mineral water *ad libitum*, and in the others they consumed a pre-determined volume of mineral water or a carbohydrate electrolyte solution (6.4% carbohydrate and 22 mM Na^+) equivalent to 1% of their baseline body mass (half before the match and half during the interval). Total water loss, sweat rate and match physiological performance were measured. When rehydrated *ad libitum* (pre-match and at half time) participants lost 1.97 ± 0.18% of their pre-match body mass (2.14 ± 0.19 L). This parameter was significantly reduced when they consumed a pre-determined volume of fluid. Sweat rate was significantly reduced when the referees ingested a pre-determined volume of a carbohydrate electrolyte solution, 0.72 ± 0.12 *vs* 1.16 ± 0.11 L/h *ad libitum*. The high percentage (74.1%) of movements at low speed (walking, jogging) observed when they ingested fluid *ad libitum* was significantly reduced to 71% with mineral water and to 69.9% with carbohydrate solution. An increase in percent movement expended in backward running was observed when they consumed a pre-determined volume of carbohydrate solution, 7.7 ± 0.5 *vs* 5.5 ± 0.5% *ad libitum*. The improved hydration status achieved with the carbohydrate electrolyte solution reduced the length of time spent in activities at low-speed movements and increased the time spent in activities demanding high-energy expenditure.

Key words: Football referee; Dehydration; Sweat loss; Performance; Fluid replacement

Introduction

Football (soccer), an endurance sport in which players perform activities of varying intensity during a 90-min match, is one of the most popular pastimes in the world. Despite the importance of referees in a football match, most studies have focused on player performance (1). Although football players and referees are exposed to identical environmental conditions, they represent different populations because during a match each plays a different role involving specific physical and cognitive demands (2). The growing economic importance of football matches in recent years has increased the physical and psychological demands imposed on referees enormously, which in turn have stimulated studies on their physical, psychological and physiological status and performance (2,3). Several studies of referees have described movement patterns (4,5), distance covered by assistant referees (6), anthropometric parameters, heart rates (4,7), and dehydration levels (8). Taken together, these results support a new specific training protocol for football referees (9).

Dehydration often occurs during physical activity and is more pronounced in endurance activities. Dehydration can be aggravated by environmental conditions that promote fluid loss (heat, humidity, lack of wind), by fluid deprivation and by high-intensity activities that require higher metabolic heat dissipation (10). Body fluid loss is promoted by physical activity during sports such as marathon races, American football, basketball, football, and hockey. Dehydration levels in football players during training sessions and actual games can oscillate between 1.70 and 3.08% of body mass (11).

In a previous study, we found that Brazilian referees suffer moderate dehydration (2% of body mass) during a

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normal football match, whereas assistant referees experience less dehydration equivalent to 1% of body mass (8). Approximately 10% of the water lost by referees comes from the vascular compartment, and the remainder from the extravascular compartments (8). Athletic performance may be compromised under moderate dehydration (2%), and this may worsen when the activity is performed in a hot environment (10,12). In addition, dehydration and hyperthermia impair the cognitive performance of athletes (13), an equally important point for football referees, who must often make crucial decisions during a game. Football refereeing is a highly intermittent exercise mode when approximately every 4 to 6 s the referee changes motion activity, covering total distances similar to those covered by midfield players (3). Thus, soccer referees experience a considerable physical demand that could be impaired by the dehydration levels observed during official matches. Several studies have reported that exercise performance is improved by the ingestion of water to offset the effects of dehydration. Also, in many situations, athletes benefit from the inclusion of carbohydrates in their rehydration protocols to supplement liver and muscle glycogen stores (13-15).

Hypohydration can affect the physical performance of referees, but this question has not been thoroughly investigated. The aim of the present study was to determine the effect of fluid replacement on the physical performance of football referees during official matches, and the relationship of performance with the type of fluid ingested.

Material and Methods

Participants and ethical procedures

Ten male football referees (field or principal referees) accredited by CBF (Brazilian Football Confederation) were used as subjects in this study. Their mean age, height, and body mass were 38 ± 1.1 years, 1.80 ± 0.02 m, and 85 ± 2.1 kg, respectively. Written consent was obtained from each individual after approval of the experimental protocol by the University Ethics Committee (Hospital Universitário, Universidade Federal do Paraná, Curitiba, PR, Brazil). All were volunteers and were informed verbally and by an informed consent form describing the nature and demands of the study, as well as about eventual health risks, which all participants signed. The participants were submitted to the official physical tests used by FIFA to evaluate its referees and to a medical evaluation prior to the study (16). All subjects were approved in both evaluations. The study was performed during official matches of the 2005 and 2006 Paraná's Football Championship (First Division), during the period from February to April. All matches were disputed at the same time, 4:00 to 6:00 pm. Care was taken to ensure that subjects maintained their normal training and professional routines during the experimental period. Ambient temperature and relative humidity data were collected from SIMEPAR, a regional meteorological bureau. The weather data were measured at fixed-site stations located in the area of the stadiums.

Experimental design and measures of hydration

The body water loss of the referees during an official match was studied on three separate occasions, in three different conditions, in an individually randomized order: 1) consumption of mineral water *ad libitum*, just as they would under normal match circumstances (pre-match and at half time); 2) consumption of a pre-determined volume of mineral water, and 3) consumption of a pre-determined volume of a carbohydrate electrolyte solution [a commercial sports drink containing 6.4% carbohydrate (sucrose-glucose-fructose mix), and 22 mM Na^+]. Mineral water density at 25°C was 0.998 g/cm^3. The individual volume of the fluid allocations was estimated on the basis of a loss of approximately 1.5% of body mass experienced by referees during an official match (8). To avoid adverse gut reactions to the volume and composition of the fluid consumed the referees received only a total volume equivalent to 1% of their baseline body mass. The ingestion of this volume was divided into two periods, one 10 min before the start of the match and the other at half time. Fluid was offered in graded cups at a temperature of 5-10°C. No food was consumed by the referees for 2.4 h before the beginning of the match, but fluid ingestion was allowed to ensure that all subjects started off in a euhydrated state. They were also instructed to consume no food and to drink only the fluid provided, from the time of the initial body mass measurement until 10 min after the match. The matches were separated by at least 1 week.

Before and 10 min after the match the referees emptied their bladders and nude body mass was then determined to the nearest 100 g using a digital balance (Plena, Model MS-601, Brazil). The referees were instructed to collect any urine passed at half time into containers provided so that this could be taken into account in the calculation of total body water loss. The difference between post- and pre-match readings, plus fluid intake during half time and the urinary volume, was used to estimate total body water loss during the match.

Sweat loss per hour was calculated from the change in body mass after correction for fluid intake and any urine passed during half time, using the following formula: pre-body mass - post-body mass + fluid intake - urine volume / duration of the match in hours. The relatively small changes in mass due to substrate oxidation and other sources of water loss, like evaporative loss from the lungs, were ignored. We considered a body mass loss of 1 kg to be equivalent to a dehydration of 1 L (17). The measurement error was 0.1 kg, i.e., ±0.14% for mass, and ±0.3% for volume.

Match analysis

Match physiological performance of football referees is usually evaluated by a time motion analysis methodology (3,18). All matches were filmed using a digital camera (Sony, model Handycam CCD-TRV 128, Japan) attached to a tripod positioned at the side of the pitch, at the halfway line, at a height of about 15 m and at a distance of about 15-20 m from the field. The camera filmed the referee close up to evaluate locomotive activities. The referees were observed during the whole match. The following locomotive categories were used: standing (0 km/h), walking (5.83 km/h), jogging (8.85 km/h), running (11.37 km/h), sprinting (18.28 km/h), and backwards running (8.85 km/h). These categories were chosen based on a previous study (5), whereas the mean speed for each category was determined after studies of the videotapes. The time for the subject to pass known distance pre-markers in the field was used to calculate the speed for each locomotive activity. The frequency and duration of each activity were digitally recorded by the same experienced observer. These data were used to calculate the distance covered by the referee in each activity. The total distance covered during each stage of the match was calculated by adding the distances covered in each motion activity. The total distance covered provides an overall index of work rate, based on the assumption that the energy expenditure during the match is directly related to total work output.

Energy expenditure values were estimated from the time the referees spent in each motor activity. Oxygen uptake during walking, running and sprinting was calculated according to the equations suggested by the American College of Sports Medicine (19). Oxygen uptake during jogging and backwards running was calculated by the equation: $VO_2 = 3.5 + (km.h^{-2} \times 0.394)$. Energy expenditure during the time subjects remained still was calculated by multiplying the basal metabolism constant 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ by the body mass. The value of O_2 consumption was then transformed to kcal by multiplying it by 5.

Blood lactate concentration

A blood sample of 50 µL was collected from a finger prick 5 min before and immediately after the match using a single-use disposable lancet. Blood lactate concentration was determined with a portable lactate analyzer (Accutrend Lactate System, Roche Diagnostics, Switzerland).

Statistical analysis

Data are reported as means ± SEM. Statistical comparisons between two means were performed by the two-tailed Student *t*-test (paired or unpaired, as applicable), whereas comparisons among multiple means were made by repeated-measures ANOVA, followed by the Student-Newman-Keuls multiple comparisons test, using the statistical software Instat 3.0 (Graphpad Inc., USA). Correlation analysis was performed by least squares regression. Values of $P < 0.05$ were considered to be statistically significant.

Results

The environmental conditions during the matches were warm, with an average temperature of 23.1 ± 0.54°C and a humidity of 67 ± 3.5%. These parameters did not change significantly among the matches. The amount of mineral water ingested *ad libitum* was 0.48 ± 0.09 L (0.06 L before the match and 0.42 L during the interval), significantly lower than that ingested by the other groups: 0.84 ± 0.04 L with the consumption of a pre-determined volume of mineral water, and 0.86 ± 0.03 L with the carbohydrate electrolyte solution (half of the volume before the match and the rest at half time).

Table 1 presents the fluid turnover data for the referees. When the participants consumed mineral water *ad libitum* they lost 1.64 ± 0.17 kg of body mass equivalent to 1.97 ± 0.18% of their pre-match body mass. This percentage of body mass loss was significantly reduced when the participants consumed a pre-determined volume of fluid. Total body water losses averaged 2.14 ± 0.19 L, equivalent to 2.48 ± 0.18% of their pre-match body mass with mineral water *ad libitum* (see Table 1). This percentage of total body water loss was also significantly reduced with the consumption of a pre-determined volume of mineral water or carbohydrate electrolyte solution. In each match the percentage of total body water loss was significantly different ($P < 0.001$) from that observed considering only the alterations of body mass (Table 1). Sweat rate was significantly reduced

Table 1. Hydration status parameters under the three fluid replacement conditions.

	Fluid *ad libitum*	Mineral water	Carbohydrate solution
Pre-BM (kg)	85 ± 2.12	86 ± 2.05	85 ± 2.30
Post-BM (kg)	83 ± 2.02	85 ± 1.97	84 ± 2.21
BM loss (%)	1.97 ± 0.18	1.30 ± 0.22*	1.02 ± 0.22*
Total body water loss (L)	2.14 ± 0.19	1.61 ± 0.20	1.46 ± 0.20
Total body water loss (%)	2.48 ± 0.18#	1.86 ± 0.22*#	1.69 ± 0.20*#
Sweat rate (L/h)	1.16 ± 0.11	0.87 ± 0.12	0.72 ± 0.12*
Urinary volume (L)	0.03 ± 0.01	0.05 ± 0.02	0.09 ± 0.03

Data are reported as means ± SEM. Pre-BM = pre-match body mass; post-BM = post-match body mass; BM loss (%) = percentage of pre-match body mass; total body water loss (L) = body mass loss (kg) + water consumed (L) + urine volume (L); total body water loss (%) = {[body mass loss (kg) + water consumed (L) + urine volume (L)] / pre-BM} x 100; sweat rate (L/h) = (Pre-BM - Pos-BM + fluid ingested - urine volume) / duration of the match in hours. *$P < 0.05$ *vs* fluid *ad libitum* (repeated-measures ANOVA, followed by the Student-Newman-Keuls multiple comparisons test); #$P < 0.001$ *vs* BM loss (%) (two-tailed Student *t*-test).

when the referees ingested a pre-determined volume of a carbohydrate electrolyte solution (Table 1).

Distances covered

The total distance covered over the period of a whole match was 9189 ± 125.3 m, and this distance was not significantly modified by fluid supplementation (Table 2). The total distance covered during the two halves was not significantly different in any of the matches studied (see Table 2 and Figure 1). The distance covered by walking when the participants consumed mineral water *ad libitum* was 4594 ± 159.3 m, and was not modified by fluid supplementation. However, the distance covered by jogging when the participants consumed mineral water *ad libitum* (2859 ± 224.0 m) was significantly reduced by fluid supplementation with mineral water: 2492 ± 220.3 m or with a carbohydrate electrolyte solution: 2357 ± 264.5 m ($P < 0.05$; Table 2). The total distance covered by high-intensity activities, running and sprinting, was: 903 ± 103.6 and 98 ± 25.8 m, respectively, with mineral water *ad libitum* and was not significantly modified by consumption of a pre-determined volume of mineral water or carbohydrate solution. There were no significant differences in these activities between the two halves in any of the experimental situations studied (Table 2, Figure 1). The total distance covered by backwards running was 733 ± 74.6 m with mineral water *ad libitum*, and increased significantly to 1024 ± 67.8 m with the carbohydrate electrolyte solution.

Percentage of time spent in each activity

During a football match the referees were standing and walking for 14 ± 1.0 and 52 ± 1.8% of the total time, respectively, and consumption of a pre-determined volume of fluid did not modify significantly these percentages. Jogging accounted for 21 ± 1.7% of the activity with mineral water *ad libitum*, a percentage that was significantly reduced by the ingestion of a pre-determined volume of mineral water: 18 ± 1.6%, or a carbohydrate electrolyte solution: 17 ± 1.1%

Table 2. Locomotive categories performed and distances covered by football referees under three fluid replacement conditions.

	Standing	Walking	Jogging	Running	Sprinting	Backward running	Total
% of the time							
Fluid *ad libitum*							
1st half	14 ± 1.4	50 ± 1.8	22 ± 1.7	5.2 ± 0.6	0.3 ± 0.09	5.5 ± 0.6	100
2nd half	14 ± 1.1	53 ± 2.1	20 ± 1.7	5.3 ± 0.6	0.4 ± 0.1	5.4 ± 0.5	100
Overall	14 ± 1.0	52 ± 1.8	21 ± 1.7	5.3 ± 0.6	0.4 ± 0.09	5.5 ± 0.5	100
Mineral water							
1st half	15 ± 1.0	50 ± 1.3	19 ± 1.5	6.6 ± 0.9	0.6 ± 0.1	7.4 ± 0.9	100
2nd half	15 ± 1.3	54 ± 1.5	18 ± 1.8	6.1 ± 0.9	0.4 ± 0.1	4.8 ± 0.5*	100
Overall	15 ± 1.0	52.3 ± 0.9	18 ± 1.6#	6.4 ± 0.9	0.5 ± 0.1	6.1 ± 0.6	100
Carbohydrate solution							
1st half	14.7 ± 0.8	51 ± 1.8	18 ± 1.7	6.0 ± 1.1	0.4 ± 0.1	8.2 ± 0.7	100
2nd half	16.0 ± 1.2	53 ± 1.8	16 ± 1.1	5.8 ± 0.4	0.4 ± 0.1	7.2 ± 0.8	100
Overall	15.4 ± 0.8	52 ± 1.6	17 ± 1.1#	6.1 ± 0.7	0.4 ± 0.1	7.7 ± 0.5#	100
Distance							
Fluid *ad libitum*							
1st half	-	2226 ± 80.6	1521 ± 114.4	448 ± 57.6	38 ± 13.1	369 ± 43.2	4603 ± 88.1
2nd half	-	2368 ± 93.4	1338 ± 119.6*	455 ± 55.1	59 ± 16.1	364 ± 39.7	4585 ± 67.3
Overall	-	4594 ± 159.3	2859 ± 224.0	903 ± 103.6	98 ± 25.7	733 ± 74.6	9189 ± 125.3
Mineral water							
1st half	-	2210 ± 57.9	1279 ± 104.2	570 ± 79.4	82 ± 26.3	495 ± 64.1	4638 ± 75.5
2nd half	-	2382 ± 67.5	1213 ± 125.9	525 ± 82.9	62 ± 17.2	322 ± 37.3*	4505 ± 91.4
Overall	-	4592 ± 85.1	2492 ± 220.3#	1096 ± 152.1	144 ± 40.7	817 ± 86.8	9143 ± 151.5
Carbohydrate solution							
1st half	-	2245 ± 82.8	1247 ± 114.5	534 ± 99.0	61 ± 17.8	545 ± 51.8	4634 ± 63.6
2nd half	-	2342 ± 83.2	1109 ± 75.1	501 ± 38.3	64 ± 19.9	478 ± 56.2	4496 ± 63.9
Overall	-	4587 ± 141.5	2357 ± 146.9#	1035 ± 132.9	126 ± 34.4	1024 ± 67.8#	9131 ± 85.2

Data are reported as means ± SEM. % of the time = percentage of the total time of each half (approximately 45 min) they expended in each activity. *$P < 0.05$ *vs* first half (two-tailed Student *t*-test); #$P < 0.05$ *vs* fluid *ad libitum* (repeated-measures ANOVA, followed by the Student-Newman-Keuls multiple comparisons test).

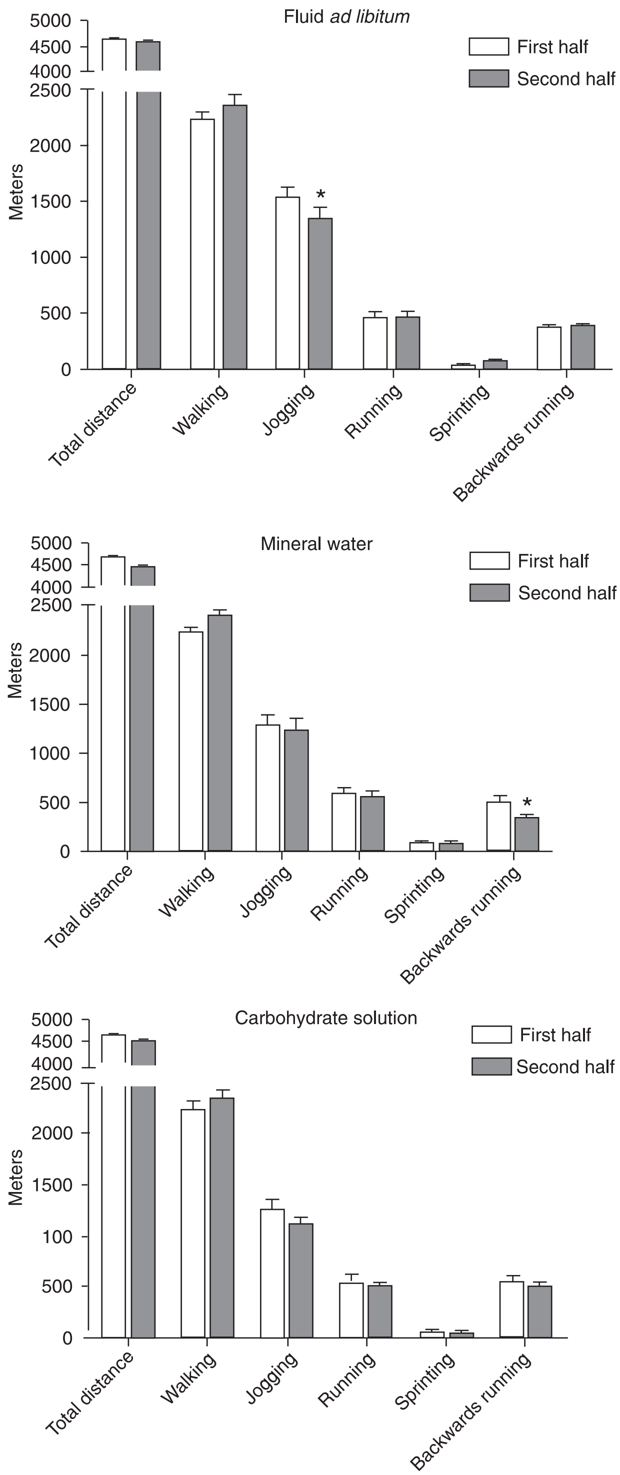

Figure 1. Distances covered by football referees in different locomotive categories during the first half (open bars) and second half (filled bars) of a match. Data are reported as means ± SEM in meters. *P < 0.05 for the difference between the first and second halves (two-tailed Student *t*-test).

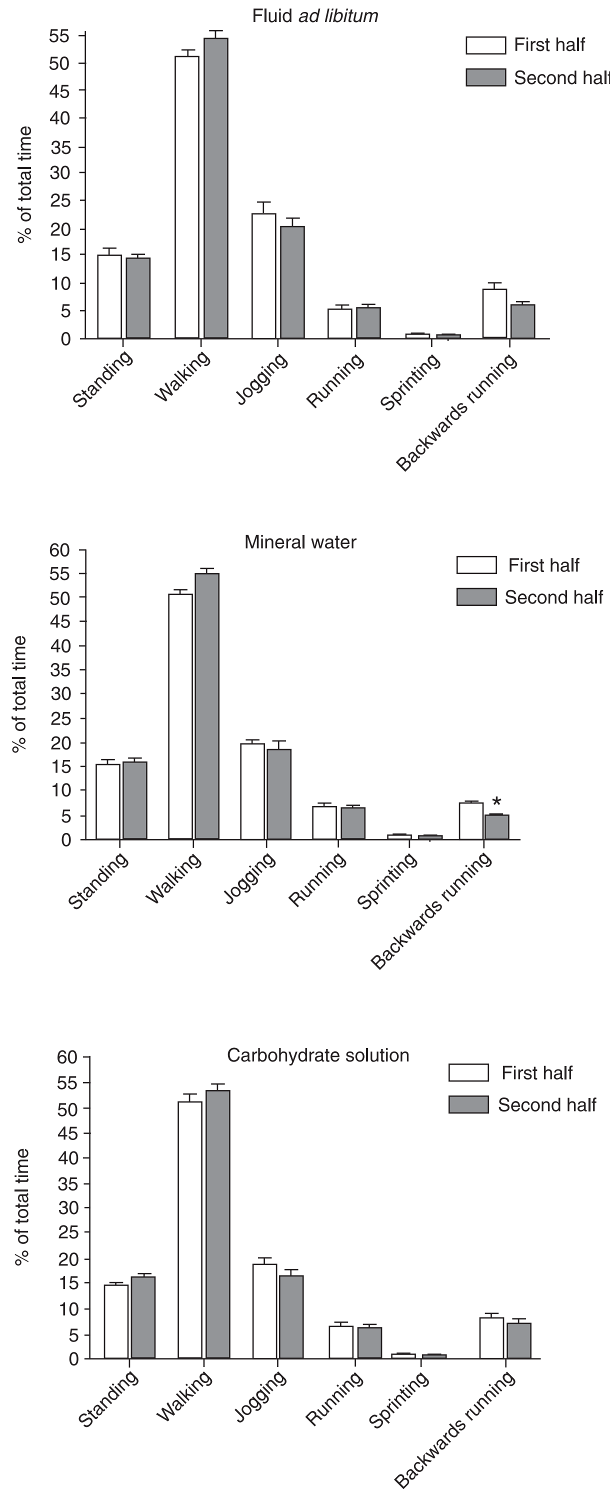

Figure 2. Activities performed by football referees in different locomotive categories during the first half (open bars) and second half (filled bars) of a match reported as percentage of total time (means ± SEM). *P < 0.05 for the difference between the first and second halves (two-tailed Student t-test).

(P < 0.05). As shown in Table 2 and Figure 2, there were no differences between the two halves for these activities.

The referees spent reduced percentages of total time performing high-intensity activities (running and sprinting). Running represented 5.3 ± 0.6% of the activity with mineral water *ad libitum* and was not significantly modified by fluid supplementation (Table 2). In all the matches observed, independent of hydration status, the referees spent less than 1% of total time performing a sprint activity. The differences between the two halves were also not significant (see Table 2 and Figure 2). On the other hand, consumption of a pre-determined volume of carbohydrate electrolyte solution caused a significant increase in the percentage of time spent in an unorthodox directional mode, backward running 7.7 ± 0.5 *vs* 5.5 ± 0.5%, with water *ad libitum* (P = 0.04; Table 2). As shown in Figure 2 and Table 2, only when the participants consumed a pre-determined volume of mineral water was the percentage spent in backward running during the second half significantly lower than in the first half: 4.8 ± 0.5 *vs* 7.4 ± 0.9%, respectively (P = 0.03).

Energy expenditure

The total energy expenditure with mineral water *ad libitum* was 735 ± 19.4 kcal, with no significant difference between the two halves. This energy expenditure was not modified by fluid supplementation: 734 ± 24.1 kcal with mineral water and 734 ± 19.4 kcal with the carbohydrate solution, respectively.

Blood lactate concentration

Blood lactate concentration with mineral water *ad libitum* was 2.5 ± 0.2 and 2.7 ± 0.3 mM before and after the match, respectively. These concentrations were not significantly different from those observed when the referees ingested a pre-determined volume of fluids.

Discussion

The present results confirm the reports that football referees usually suffer from moderate dehydration (~2.48% of body mass) during official football matches. This water loss can be reduced significantly by the consumption of a volume of fluid (mineral water or carbohydrate electrolyte solution) equivalent to 1% of their baseline body mass before the match, thereby improving fluid replacement. The use of the carbohydrate electrolyte solution reduced the length of time spent in activities involving low-speed movements (walking and jogging) and increased the time spent in activities demanding high-energy expenditure (backward running).

The amount of fluid lost by sweating depends on exercise intensity, environmental conditions, baseline hydration status and individual differences. Athletes such as football players become dehydrated if sweat loss exceeds fluid intake (17). Changes in body mass are routinely used in field studies to assess the hydration status of athletes (14). In the present study, football referees lost 2.14 ± 0.19 L of total body water when rehydrated with mineral water *ad libitum*, which is equivalent to 2.48 ± 0.18% of body mass. However, body mass was reduced by 1.97 ± 0.18%, suggesting that spontaneous water intake immediately before the match and during the half time break restored only 22 ± 2.6% of the fluids lost (Table 1). Therefore, the moderate dehydration that occurred during the match was not compensated by spontaneous water intake. The fluid intake of 0.45 ± 0.09 L was apparently not correlated with total water loss (r^2 = 0.077, P = 0.434). Therefore, referees did not realize that they needed fluid replacement. "Thirst mechanisms" are known to compel people to drink at a rate that replaces approximately one-half of their fluid losses, resulting in "voluntary dehydration" (20). Our results corroborate this idea.

To date, only a few studies have investigated fluid loss in football referees. We agree with the findings of Da Silva and Fernandez (8) and Krustrup and Bangsbo (18) who reported moderate dehydration in football referees (from 2 to 2.5%). In contrast, several studies on football players during matches and training sessions have shown a marked variation in water loss (1.7 to 3.1% of body mass) (11,21). Particularities in the experimental protocol and the environmental conditions of each study may account for these differences. Environmental factors such as temperature, relative humidity and wind speed are known to have a major influence on sweating response and heat loss by evaporation from the skin surface (13). In addition, differences in fluid consumption during physical activity and match intensity make it difficult to compare the dehydration levels of referees and football players if they are evaluated separately. Therefore, future studies are necessary to compare the dehydration levels of football referees and players in a same match.

The National Athletic Trainers Association recommends fluid replacement before, during and after competition (14). Fluid replacement should approximate sweat and urine losses and ensure that body mass loss after exercise does not exceed 2% (14,22). Therefore, in the present study, we rehydrated the referees with a fluid volume equivalent to 1% of their baseline body mass. Because referees lose approximately 1.5% of body mass during an official match (8), we decided to replace fluids at a low proportion to avoid adverse gut reactions. The rates of substrate and water supply during exercise are in fact limited by intestinal absorption capacity (23).

When the referees consumed a pre-determined volume of mineral water, equivalent to 1% of their baseline body mass (0.84 ± 0.04 L), they lost 1.86 ± 0.22% of body water, whereas body mass was reduced by 1.30 ± 0.22%. This indicates a higher restitution of the fluids lost during the match (37 ± 8.4%) compared to the *ad libitum* situation. The hydration status of referees was improved in this protocol compared to spontaneous intake ($P < 0.05$) because of the higher fluid consumption. In a recent review, Coyle (15) concluded that 1-2% dehydration is tolerable in temperate environments and that losses in excess of 2% of body mass are tolerable in cold environments. Earlier studies also suggested that complete replacement of fluid losses is not essential, and that greater levels of dehydration are acceptable when the thermal environment is less challenging. Along these same lines, Noakes (24) argues that drinking more than *ad libitum* does not provide an additional improvement of physical performance. Another point to take into account is that excessive water intake (>1.5 L/h) may induce signs and symptoms of hyponatremia, with a potentially fatal outcome (24). Therefore, athletes can safely maintain low levels of dehydration by drinking enough water during exercise, but not in excessive amounts.

Some studies have suggested that athletes who participate in events lasting longer than 1 h should consume fluids containing carbohydrates and electrolytes rather than water alone (25). We found that referees who ingested a pre-determined volume of carbohydrate electrolyte solution (0.87 ± 0.03 L) experienced the lowest body water loss (1.69 ± 0.20%) and highest restitution of the fluids lost during the match (44 ± 6.2%). The presence of carbohydrates in the ingested fluids increases intestinal water absorption, a fact that might explain the better results compared to fluid replacement with mineral water.

Dehydration and performance

Dehydration of >2% of body mass degrades aerobic exercise and cognitive/mental performance in temperate-warm-hot environments (10). Recent publications have reported the negative effects of mild dehydration on health and human performance (26). With a small reduction of 1 or 2% of body mass (a percentage similar to that found in football referees), exercise performance capacity, cognitive function, and alertness decline, whereas heart rate increases (27). Data describing the effects of body water deficit on football player performance are scarce (21), and information on elite players or referees is nonexistent. In addition, environmental temperature should be considered because the same dehydration levels may be tolerable at moderate temperatures (20°C) but compromise athlete performance at higher temperatures (>30°C) (12). The matches studied here were played at an average temperature of 23.1°C, which probably attenuated any decrease in physical and mental performance caused by temperature extremes.

To evaluate the physiological performance of football referees during the match we used time motion analysis. The referees covered an average distance of 9189 ± 125.3 m (8411-9765 m) when rehydrated with mineral water *ad libitum*, similar to that observed in other studies (4,18) and lower than the 11,218 ± 293 m reported by Castagna et al. (3) for international-level Italian referees. The total distance covered by the referees during the match is similar to that described for football players, in particular for midfield players (1,28). This distance was not significantly modified by fluid supplementation. Differences in the distances covered by referees may be related to the competitive level of the official matches analyzed and/or to match-to-match variability, as described recently for football players (29). Football refereeing involves high-intensity intermittent exercise, during which referees alternate between low-intensity episodes (standing, walking, jogging) and high-intensity (running and sprinting) activity (3,18). In other words, football referees expend a significant amount of aerobic energy throughout a match and experience episodes of considerable anaerobic energy turnover. In this respect, the production of aerobic energy accounts for approximately 90% of total energy consumption (30). However, this proportion is inter-individually variable because different factors affect exercise intensity. The referees studied here spent 52% of match time walking, 21% jogging and 14.5% standing. This prevalence of low speed movements (walking and jogging), ranging from 41.8 to 73.8%, was also observed in other studies and also with football players (1,4,5,18). Game style and match intensity should also be considered when comparisons are made with matches played in different countries (31). The work rates of referees have also been associated with the physical activities of the players in a same match (32). The referees studied by us had a high proportion (74.1%) of low speed movements (walking and jogging), possibly resulting from the low match intensity of the regional championship in which they officiated and/or differences in game style between South American and European players. This percentage of low-speed movements decreased significantly when the referees consumed a pre-determined volume of fluids, reaching 71% with mineral water and 69.9% with the carbohydrate solution ($P < 0.05$).

Football referees seldom run at maximum effort (sprinting) or at high-intensity speeds (running). We found that this represented only 5.6% of the match time and that it did not increase significantly with the fluid replacement protocols (6.9% with mineral water and 6.5% with the carbohydrate solution). In similar studies, time spent engaged in high-intensity activities in a match varied from 4 to 18% (4,18) and was lower in the second half (18). This result suggests that referees experience fatigue towards the end of the match. We did not observe such an activity reduction in the second half. On the other hand, football players performed more high-intensity running and sprinting than referees (1).

However, referees when consuming a pre-determined volume of carbohydrate solution increased backward running rates. According to other studies, backward running is more demanding in terms of energy expenditure than forward running (33). Factors such as depletion of glycogen stores, dehydration and hyperthermia may contribute to the development of fatigue in the later stages of a football game. To date, this has been studied in football players rather than in referees (34). Referees under the carbohydrate protocol increased their motor activity rate with higher energy expenditure, indicating improvement in physical performance and reduction in body water loss. Several investigators have reported positive effects of carbohydrate electrolyte solutions on the performance of football players (35). Carbohydrates may be helpful in these circumstances because: a) at the end of a football match most players are depleted of muscle glycogen (36), and b) players with a low glycogen content run less and perform fewer sprints than those with normal glycogen content, especially during the second half (37). Clarke et al. (38) observed that timing and volume of fluid ingestion do not affect the metabolic responses or performance of football players if a same volume of carbohydrates is consumed. On the other hand, Zeederberg et al. (39) did not find measurable improvements in the motor skill proficiency of football players as a result of ingesting a glucose polymer solution.

Despite the small differences in motor activity patterns between referees subjected to the different fluid replacement protocols, their energy expenditure (735 ± 19.4 kcal) was similar to that observed in a previous study conducted by our group (5). Direct measurements of oxygen consumption in soccer players during a match reported a value of energy expenditure of 1195 kcal, and the value estimated by the recording of heart rate was 1565 kcal (40). If we take into consideration the fact that a male person consumes, on average, 2900 kcal/day (National Research Council, 1996), then the referee's energy demand during a match would be from 3500 to 4000 kcal/day. A professional soccer player, in order to cope with the daily physical activity and the physical effort due to soccer training and competition, should consume 3500 to 4500 kcal/day (34,40). A soccer player's training is generally more frequent and longer in duration than that of a referee, with a higher energy cost (34). Since the energy expenditure of referees is lower than that of a player during a match, their energy needs to support daily physical activities (training and refereeing) will generally be lower. Therefore, the nutritional habits must be adapted to their daily physical activities, short training periods and physical activity of moderate energy intensity, on average, during match refereeing.

The adoption of a specific fluid replacement protocol was able to significantly reduce the total body water loss of male football referees during official matches. The improved hydration status achieved with the carbohydrate electrolyte solution reduced the length of time spent in activities at low-speed movements (walking and jogging) and increased the time spent in activities demanding high-energy expenditure (backward running). This finding suggests that the use of rehydrating fluids by football referees during official matches should be systematic. Further study is required to examine whether improvement in hydration status affects other parameters such as distance from players' violations and cognitive performance.

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