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HYDRATION STATUS OF MALE FOOTBALL PLAYERS ACROSS A WEEK OF TRAINING AND COMPETITION

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Abstract

Introduction: Acute body mass loss >2% has been associated with an impairment of exercise performance, particularly in hot conditions. The aim of this study was to investigate hydration status over a period of training and competing in the New Zealand Football Championship league during the summer.

Methods: Daily hydration status was determined by urine specific gravity (USG) from first void urine samples collected over 8 days, including 4 days of training and 1 day of competition. Acute changes in hydration status as a result of training and competition were estimated from body mass change. Sweat loss was calculated from body mass change taking into account fluid intake and urinary loss.

Results: Mean net change in body mass during training for all players who completed training (n=12) was +0.40 ± 0.75% and all who completed a full game (n=7) was -3.02 ± 1.08%. Mean net body mass change in players who completed both training and competition (n=5) was -1.03 ± 0.28% and -3.45 ± 0.96%, respectively. Body mass change, fluid intake, sweat loss and sweat rate were greater (P < 0.05) during competition than training in those who completed both. Players were hypohydrated (USG > 1.020) on all mornings except competition day. Training did not affect hydration status, as indicated by USG the following morning.

Conclusion: Hydration status across an extended period of repeated training and competition appears to be suboptimal. Net fluid balance during training and competition is highly variable, with some players overhydrating in training. Acute body mass loss is inevitable with football and is best managed by individualized drinking strategies that prevent weight gain or large loss during training and competition. Monitoring daily hydration status prior to subsequent endeavor may help maintain euhydration.

Key words: *fluid balance, dehydration, alcohol, Urine Specific Gravity, body mass loss*

Introduction

Dehydration has been associated with impaired exercise performance, including football performance attributes [1, 2]. There are currently limited data available on how hydration status varies over consecutive days encompassing training and competition in football players. Most research to date has only focused on acute changes during training or competition. In one study, the acute effects of training and competition on hydration have been measured in the same group of players [3] and in one other study the hydration status across three consecutive days of training was evaluated [4]. Silva et al. [4] noted that measures of pre-training hydration indicated that many players started training sessions in a hypohydrated state and that although mean body mass loss during training was less than 2%, there was a large range to a maximum of 3.9%. A 1-2% loss in body mass is common during soccer training (3, 5-8), with typically greater losses (>2%) observed during competition [2, 9, 10]. Considerable individual variation exists between players, and fluid intakes are often insufficient to compensate for sweat losses during training and particularly during competition, across a range of climatic conditions [3, 5-11]. Understanding the fluid intake requirements of players is important when attempting to manage hydration status and thereby optimize performance [1, 2].

The aim of this study was to investigate hydration status across a week, including training and competition, and the acute effects of both on fluid losses in male football players.

Material and methods

Subjects for this observational study were Otago United Football Club first team players playing in the New Zealand Football Championship league (NZFC) during the 2007–2008 summer season. Approval to conduct the study was obtained from the Otago University Ethics Committee and written informed consent was obtained. Data were collected on body mass change and fluid intake during one training session and one competition game, across one week, using the same study protocols (Fig. 1). Urinary measures were taken each day for eight consecutive days, encompassing training and competition, to assess changes in hydration status across the period. Training was 90 min in duration and consisted of a warm up, an incremental shuttle run test, ball skills and a 7-a-side game. All pre-training measurements were completed within half an hour of the start of training. The mean (± SD) temperature and

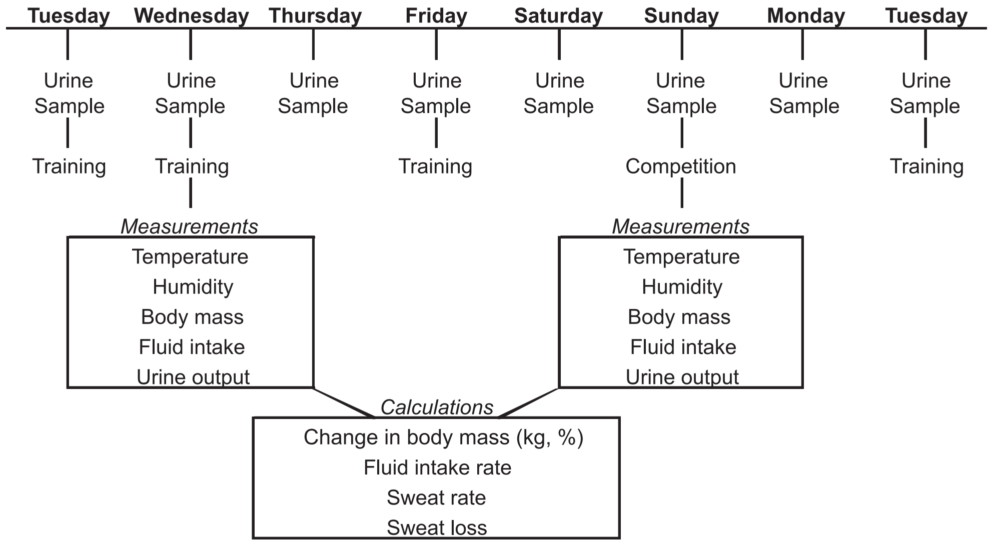

Fig. 1. *Overview of study design*

humidity during this training day were 24.5 ± 5.4°C (range 18.0–29°C) and 52.3 ± 15.1 % (range 39–72%), respectively. The competitive game was 96 min in duration (2 x 45 min + 6 min extra time) and included a 34 min warm up consisting of sprints, dynamic exercises and ball work. All pre-competition measurements were completed within an hour of the competitive game. The mean temperature and humidity were 32.4 ± 2.4°C (range 28.5–35.2°C) and 36.4 ± 5.2% (range 28–42%), respectively, during competition.

On arrival at training and competition players were asked to empty their bladders before pre-exercise measurements were taken. Nude pre-exercise body mass was determined using digital scales (A&D Co. UC-300, Tokyo, Japan) accurate to 50 g. Players' drinking bottles were labeled with their squad number, filled and weighed prior to training and competition using digital scales (Salter 1017, Tornbridge, England). If further fluid was required, residue in the drinking bottle was weighed before refilling and weighed again when full. A sports re-hydration drink (Horleys Replace [7.5% carbohydrate, 25 mmol/L Na^+], Auckland, New Zealand) as well as water or their own beverage were available during competition, however, only volumes were recorded, not specific beverage. Fluid intake was ad libitum and players had full access to their preferred fluid(s). Players were instructed to drink from their own bottles and to not use drinking fluid for any other reason than drinking. Additional water was provided for other uses such as mouth rinsing. Players were instructed to collect any urine passed during training and competition into pre-weighed containers. If the bathroom was required, players were weighed before and after their visit. At the end of training and competition, post-exercise body mass was determined by weighing players in the nude after they had toweled down and drink bottles were weighed. All players trained in the same clothes (shorts, shirt and socks) and played the competitive game in the same uniform. Five research assistants took measurements and observed compliance of the players.

Chronic (day to day) hydration status was determined by measuring urine specific gravity (USG) of samples from the first void in the morning. Players used containers labeled with name and day. All urine samples were frozen to -4° C and analyzed in duplicate within one week of collection. USG was determined using a hand held Refractometer (Atago Urine Specific Gravity Refractometer No 2720-E01, Uricon-N, Tokyo, Japan) which was calibrated after every ten measurements using distilled water. A USG of >1.020 was used as a threshold for dehydration. On completion of the study players were required to complete a questionnaire about alcohol consumption and illness involving diarrhea or vomiting.

Sweat loss was estimated from body mass change corrected for fluid intake and urinary and fecal losses with the following equation:

Sweat Loss (ml) = Decrease in body mass (kg) + fluid intake (L) – urine and fecal output (L) x 1000

Sweat rate was calculated by dividing sweat loss by duration (min) of training or competition for players that completed full sessions and partial time played by substitutes, as well as warm up play.

Statystical analysis

The measured changes between training and competition were assessed using the Statistical Package for Social Sciences software (SPSS version 12.0). The difference between means for training and competition were analyzed using unpaired *t*-tests. Paired *t*-tests were used to assess the difference between means for players who completed both training and competition. Statistical significance was accepted with a *P*-value of < 0.05.

Results

Player characteristics

Seventeen players volunteered to participate in this study. Fourteen players completed the urine sampling and end of study questionnaire. Twelve players completed the training protocol, seven completed the full competition game, six completed training and were substitutes and five completed both the training on the day of measurement and the whole competition game. Participation in complete data collection was limited by lack of completed training and competition due to illness, injury and/or selection for and/ or substitution in the competition game. All results reported are from outfield players (defenders, midfielders and attackers) only. The mean (±SD) age, height and mass for all 17 players were 24.8 ± 3.9 yr, 1.78 ± 7.9cm, and 72.7 ± 7.6 kg, respectively. Body mass for those who completed training (*n*=12) was 72.65 ± 7.63 kg and for those who completed both training and competition (*n*=5) was 79.62 ± 1.73 kg.

Fluid gains and losses during training and competition

Absolute and percent changes in body mass, fluid intake and sweat loss during training and competition in all players, including substitutes, are presented in Table 1. All measurements were significantly greater during competition than training ($P<0.05$). In total, nine of twelve players lost mass during training, three gained mass during training and all players, including substitutes, lost mass during competition. Absolute and percent decrease in body mass, fluid intake and sweat loss for only those players who completed both training and competition are presented in Table 2. All five players lost mass after training and competition, with a mean of 1.95 kg more lost after competition than training ($P<0.05$). Significant differences between training and competition were also observed for fluid intake and sweat loss. Individual fluid intake and sweat loss for players who completed both training and competition are presented in Figure 2. Mean sweat rates, calculated using the duration of training and competition, were 988 ± 164 ml/hr and 1786 ± 262 ml/hr, respectively.

Chronic hydration status

Fourteen players each provided eight consecutive first void urine samples. Mean USG on seven of the eight days was >1.020 and no effects of training were observed (Table 3.). In players who completed both training and competition mean USG remained unchanged after training (Wed vs. Thurs. $P>0.05$), however, there was a trend for USG to increase after competition (Sun. vs. Mon. $P=.074$) (Table 3). Mean USG in the players who completed the game was >1.020 for all days except Sunday morning (competition day) (Fig. 3).

All fourteen players who provided eight first void urine samples completed the end of study questionnaire. Alcohol was consumed on at least one occasion during the eight days by 12 players with at least five players consuming >5 alcohol units on more than three occasions. Six players reported consuming alcohol the night before training, however, all players abstained the

Table 1. *Body mass change, fluid intake and sweat loss for training, competition and substitutes*[1]

	Change in Body Mass (kg)		Change in Body Mass (%)		Fluid Intake (ml)		Sweat Loss (ml)	
Training (*n*=12)	+ 0.36 ± 0.54	(-0.60 - +1.15)	+0.40 ± 0.75	(-1.02 - +1.03)	810 ± 250	(550 - 1270)	1142 ± 358	(645 - 1811)
Competition (*n*=7)	-2.38 ± 0.91*	(-3.90- -1.40)	-3.02 ± 1.08*	(-4.87 - -1.08)	1650 ± 680*	(870 - 2560)	3479 ± 811*	(2126 - 4422)
Substitutes2 (*n*=6)	-0.85 ± 0.60	(-1.80- -0.25)	-1.19 ± 0.76	(-2.29 - -0.36)	1647 ± 497	(1041 - 2362)	2010 ± 973	(1124 - 3692)

[1] Data are expressed as mean ± SD (range)
[2] Substitutes played from 22-74 min of the game
* Significant difference between training and competition (unpaired *t-test*, $P<0.05$)

Table 2. *Body mass change, fluid intake and sweat loss for players who completed both training and competition*[1]

	Change in Body Mass (kg)		Change in Body Mass (%)		Fluid Intake (ml)		Sweat Loss (ml)	
Training (*n*=5)	-0.82 ± 0.22	(-1.15- -0.55)	-1.03 ± 0.28	(-1.47- -0.69)	662 ± 90	(550 - 800)	1482 ± 246	(1188 - 1811)
Competition (*n*=5)	-2.77 ± 0.75*	(- 3.90- -1.95)	-3.45 ± 0.96	(-4.87 - -2.41)	1726 ± 810*	(870 - 2556)	3839 ± 562*	(3261 - 4422)

[1] Data are expressed as mean ± SD (range)
* Significant difference between training and competition (paired *t-test*, $P<0.05$)

Table 3. *Morning urine specific gravity collected from first void in all football players sampled each day (n=14) and in those who completed training and the whole competition game (n=5)*

	TuesT	WedT	Thurs	FriT	Sat	SunC	Mon	Tues
All (*n*=14)								
	1.024	1.022	1.021	1.018	1.025	1.021	1.022	1.022
	±0.005	±0.006	±0.006	±0.006	±0.004	±0.006	±0.005	±0.005
Competition (*n*=5)								
	1.025	1.023	1.023	1.021	1.023	1.017	1.022	1.024
	±0.002	±0.006	±0.006	±0.004	±0.005	±0.007	±0.005	±0.003

[1] Data are expressed as mean ± SD
T Training day
C Competition day

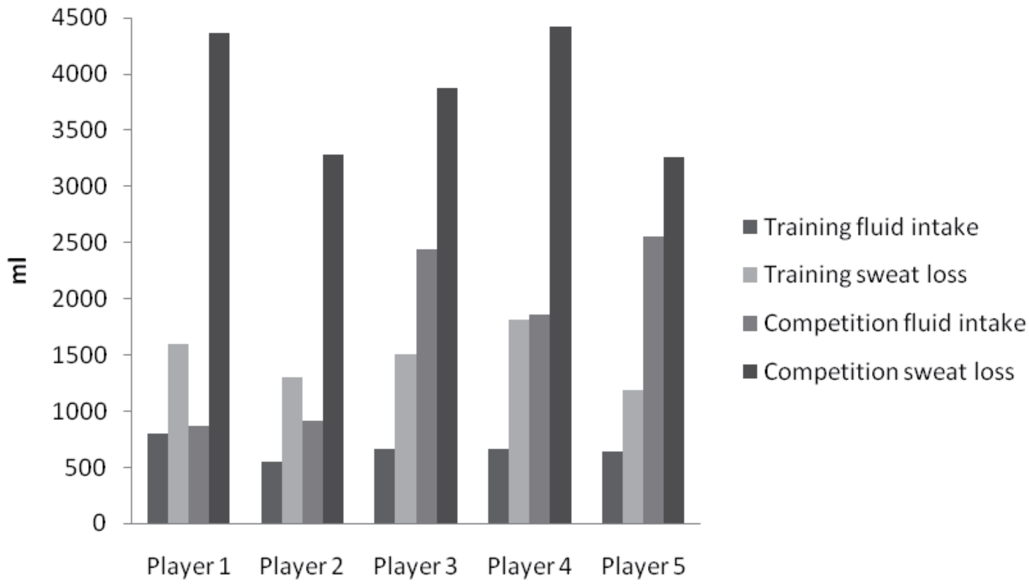

Fig. 2. *Fluid intake and sweat loss during training and competition for players who completed both training and competition (n=5)*

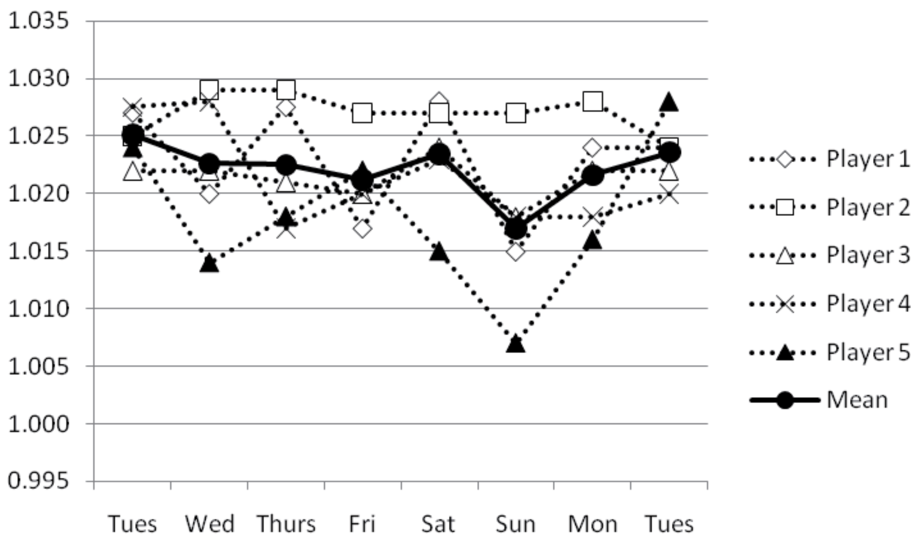

Fig. 3. *Morning urine specific gravity collected from first void in football players who completed both training and competition. Training was on Tuesdays, Wednesday and Friday and competition was on Sunday.*

night before competition. No players reported diarrhea or illness during the study, however, two players reported alcohol related vomiting.

Discussion

The main finding from this study is that players may be insufficiently hydrated over consecutive days encompassing several training sessions, and although mean net fluid balance during training may be slightly positive, many players clearly over- or under-hydrate during training sessions and may come to training in a compromised hydration state.

Day to day hydration status, as indicated by morning USG, was highly variable yet it appeared that the players more conscientiously hydrated prior to competition. The USG results may have been confounded by alcohol consumption which was not infrequent in most players during the study period excepting the evening prior to competition. The small sample size must, however, be considered when interpreting results.

Silva et al. [4] monitored hydration status over three consecutive days of training and also observed that players were hypohydrated prior to training (mean USG > 1.020), however, they did not take first void urine samples and beverage intake prior to the sampling was not controlled, which would have increased variability. Although USG is relatively accurate in dynamic hydration assessment, particularly when morning first void is used, it is less so as an absolute measure [12] and its response is delayed [13].

This finding of hypohydration during a period of training might also be related to inadequate replacement of sodium as total body water restoration is reliant on sodium. Maughan and Leiper [14] have shown that after dehydrating exercise urinary output is greater when no or lower sodium intake occurs with fluid replacement than when more sodium is ingested and, thus, a delay in reinstatement of fluid balance occurs as evidenced by a slower restoration of plasma volume.

When comparing the present results with those of other studies, similarities as well as differences were noted with regard to fluid balance during training. Mean fluid intake was similar to that reported by Shirreffs et al. [5] in a review of three studies [6-8] in which the acute effects of training on hydration status in cool, temperate and hot conditions were investigated. The average sweat loss and percent decrease in body mass in those studies reviewed was much greater than in the current study; all 67 players reported on lost weight. Maughan et al. [8] reported greater mean fluid intake, sweat loss and percent decrease in body mass during training, although conditions were only slightly warmer. This may reflect a difference in training regime or intensity at which players trained, and thus greater sweat losses, as they were professionals playing at a much higher level than the amateur players of Otago United. Fluid balance is equally related to intake. In the present study fluid intake was greater than that reported by Broad et al. [3] in 32 elite players during summer training (> 20°C) in Australia and resulted in a smaller percent decrease in body mass.

In the present study three players lost between 1-2% body mass during training with no players losing >2%. Three players also gained mass. Although preventing dehydration by reducing body mass loss to <2% is important, excessive fluid consumption during training is not only unnecessary, but may be detrimental. The finding of individual cases of over-hydration during training has not been frequently reported, possibly due to an emphasis on mean values. Several authors [4, 9, 15, 16] have noted individual cases of over-hydration (gain in body mass) during training sessions. Moreover, Shirreffs & Maughan [16] observed an overall mean gain of 0.4% body mass, similar to that observed in the current study. Even if body mass was unchanged this would represent over-hydration as some loss is due to substrate metabolism with exercise of this duration (60-70 min).

Impaired endurance performance is generally observed with losses of more than 2% in warm and hot climates with players better able to tolerate similar losses in cool environments [17, 18]. With regard to football, Edwards et al. [1] reported a decrement in a sport-specific fitness test with 2.4% mass loss versus 0.7% loss, including a 13-15% decrease in total distance covered and Mohr et al. [2] observed a 2.6% decrease in repeated sprint performance and an 8.2% decrease in jump performance after a game in which 2% of the body mass was lost. In the present study, the majority of players were able to manage their hydration status well, with no players losing more than 2% body mass, although a wide inter-individual variation was observed. The most recent ACSM position stand on fluid and electrolyte replacement acknowledges this variability and accordingly recommends customized fluid replacement strategies, not to prevent any change in mass, but to limit loss to less than 2% [19].

Competition presents increased challenges to managing fluid needs. In the present study all players lost mass during competition with one player having lost over 4.0% of his initial body mass, while another lost only 0.09% body mass. Sweat rates during competition were highly individual and ranged from 989 to 2057 ml/hr. In the five players who completed both training and the full competition game body mass loss was more than three times greater during competition than during training, as a result of sweat losses being almost three times greater. This is a reflection of the greater duration of the game and greater intensity and temperature that the competition game was played at when compared to training. Aragón-Vargas et al. [20]

recorded deficits of a similar magnitude and range (mean 3.4% range 1.7 - 5.3%) as a result of competition, also in warm conditions (35° C). A decrease in body weight of 1–2 kg has previously been reported by Ekblom [21] during competition in a temperate climate with weight loss being greater during international level competition. Mustafa and Mahmoud [10] reported body mass losses of ~3% in international level players competing in the hot environments of Somalia and Sudan. In the cooler conditions of Tunisia the same players lost only 1.2% body mass and had a reduced mean sweat loss. Allowing for differences in fluid losses attributable to differences in climate, increased sweat losses and a greater net mass loss with competition than training is commonly observed. This may be explained by the greater intensity of exercise for longer periods. The current study was conducted in temperatures slightly less than those reported in a study of elite Kuwaiti football players [9]. The mean fluid intake of Kuwaiti players during competition was less than that observed in the current study, even though the range of fluid intakes was similar. Players replaced, on average, 47% of their sweat losses, which is similar to that reported by Broad et al. [3] in temperate conditions. Mean fluid intake doubled during competition when compared to training, suggesting players were aware of their increased fluid requirements, however, only a similar proportion of sweat loss was replaced and therefore a greater net loss ensued.

The finding of inadequate intake during competition is in line with other research on the effect of competition on hydration status in temperate and hot environments [3, 5, 6, 8-10, 21]. Broad et al. [3] reported players increased their rate of fluid intake during competition, regardless of season. Participants in the present study also increased their fluid intake during competition but, this was not sufficient to offset the increased sweat loss. Although the rules of football and limited stoppages in play may make drinking during competition difficult, it is doubtful that this was the primary impediment to achieving fluid balance as the volume ingested during competition did increase. With a mean fluid intake of 1.7 L over the course of the game it is possible that this rate of fluid ingestion is close to the maximal gastric emptying rate and tolerance to gastric fullness [22]. The increased fluid needs and limited ability to replace fluid lost during competition accentuate the importance of pre-game hydration status to optimize fluid balance. The wide individual variation in sweat losses, and therefore fluid needs, makes blanket recommendations for fluid intake impossible. Simply encouraging all players to drink is clearly insufficient and may result in inappropriate fluid intakes that could compromise performance and health.

Conclusions

The present USG data indicate that football players may be chronically hypohydrated during periods of training. However, according to USG levels, by the morning of competition players are able to achieve euhydration. The role of alcohol consumption on hydration status over a period of repeated training, and on accuracy of USG monitoring, deserves further attention. We observed a poor match of fluid intake with losses in both training and competition. In training, this mismatch included under- and over-hydration, while in competition only under-hydration was observed. During competition intensity of exercise and difficulty in accessing fluids are considerations. Nevertheless, the present findings do not support recommending that all players be encouraged to maximize fluid intake. Drinking strategies should be based on individual needs and tolerance, tailored to environmental conditions and to the type of session being conducted.

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References

1. Edwards AM, Mann ME, Marfell-Jones MJ, et al. Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. *Br J Sports Med* 2007; 41(6): 385-91.
2. Mohr M, Mujika I, Santisteban J, et al. Examination of fatigue development in elite soccer in a hot environment: a multi-experimental approach. *Scand J Med Sci Sports* 2010; 20: 125-32.
3. Broad E, Burke L, Cox G, et al. Body weight changes and voluntary fluid Intakes during training and competition sessions in team sports. *Int J Sport Nutr Exer Metab* 1996; 6(3): 307-19.
4. Silva AD, Fernandez R. Dehydration of football referees during a match. *Br J Sports Med* 2003; 37: 502-6.
5. Shirreffs S, Sawka M, Stone M. Water and electrolyte needs for football training and match play. *J Sports Sci* 2006; 24(7): 699-707.
6. Shirreffs S, Aragon-Vargas L, Chamorro M, et al. The sweating response of elite professional soccer players to training in the heat. *Int J Sports Med* 2005; 26(2): 90-5.
7. Maughan R, Shirreffs S, Merson S, Horswill C. Fluid and electrolyte balance in elite male footbal (soccer) players training in a cool environment. *J Sports Sci* 2005; 23: 73-9.
8. Maughan R, Merson S, Broad N, Shirreffs S. Fluid and electrolyte intake and loss in elite soccer players during training. *Int J Sport Nutr Exerc Metab* 2004; 14: 333-46.
9. Al-Jaser T, Hasan A. Fluid loss and body composition of elite Kuaiti soccer players during a soccer match. *J Sports Med Phys Fitness* 2006; 46(2): 281-5.
10. Mustafa K, Mahmoud N. Evaporative water loss in African soccer players. *J Sports Med Phys Fitness* 1979; 19: 181-3.
11. Maughan R, Shirreffs S. Urine osmolality and conductivity as indices of hydration status in athletes in the heat. *Med Sci Sports Exerc* 1998; 30(11): 1598-602.
12. Cheuvront S, Carter R, Sawka M. Fluid balance and endurance performance. *Current Sports Medicine Report* 2003; 2(4): 202-8.
13. Oppliger R, Bartok C. Hydration testing of athletes. *Sports Med* 2002; 32: 959-71.

14. Maughan R, Leiper J. Sodium intake and post-exercise rehydration in man. *Eur J Appl Physiol* 1995; 71(4): 311-9.
15. Kurdak SS, Shirreffs SM, Maughan RJ, et al. Hydration and sweating responses to hot-weather football competition. *Scand J Med Sci Sports* 2010; 20: 133-9.
16. Shirreffs SM, Maughan RJ. Water and salt balance in young male football players in training during the holy month of Ramadan. *J Sports Sci* 2008; 26(1 supp 3): 47-54.
17. Coyle E. Fluid and Fuel Intake. *J Sports Sci* 2003; 22: 39-55.
18. Murray B. Hydration and physical performance. *J Am Coll Nutr* 2007; 26(5): 542S-8S.
19. Sawka MN, Burke LM, Eichner ER, et al. American College of Sports Medicine position stand. Exercise and fluid replacement. [Practice Guideline Review]. *Med Sci Sports Exerc* 2007; 39(2): 377-90.
20. Aragón-Vargas LF, Moncada-Jiménez J, Hernández-Elizondo J, et al. Evaluation of pre-game hydration status, heat stress, and fluid balance during professional soccer competition in the heat. *Eur J Sport Sci* 2009; 9(5): 269-76.
21. Ekblom B. Applied physiology of soccer. *Sports Med* 1986; 3: 50-60.
22. Mitchell JB, Voss KW. The influence of volume on gastric emptying and fluid balance during prolonged exercise. *Med Sci Sports Exerc* 1991; 23(3): 314-9.

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