Hydration Status, Fluid Intake, and Electrolyte Losses in Youth Soccer Players

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The purpose of the study was to determine the hydration status, fluid intake, and electrolyte losses of 21 male professional youth soccer players (age 17.1 ± 0.7 y) training in a cool environment. Pretraining and posttraining measurements of body mass, urine (freezing-point osmolality method), and sweat concentration (flame-emission spectroscopy) were collected. Fourteen players were found to be hypohydrated before training. The amount of fluid lost due to exercise equated to a 1.7% loss in body mass, which equated to a gross dehydration loss of 0.5%. Overall, the soccer players replaced 46% ± 88% of sweat loss during training, and only 4 remained hypohydrated after training. No significant correlations between sweat loss and sweat concentrations of Na⁺ (r = −.11, P = .67) or K⁺ (r = .14, P = .58) were found, but there was a significant correlation with Mg²⁺ (r = −.58, P < .009). This study found large variability in pretraining hydration status that the players were able to rehydrate during the training sessions. However, given the numbers starting training in a hypohydrated state, adequate hydration status before training should be considered by youth players, coaches, and sports-science support staff.

Keywords: training, dehydration, urine osmolality

Most data on fluid intake and consequent changes in body mass for youth have been collected in warm or hot environments.¹⁻³ This information has been used to help formulate guidelines for fluid replacement, principally to reduce the effects of heat illness but also to optimize performance. However, whether these fluid guidelines are applicable to athletes training or competing in a colder environment is unclear. Broad et al.⁴ reported mean sweat rates in adolescent male soccer players (age 16–18 y) at the Australian Institute of Sport of 1027 mL/h during competition at 10°C and 746 mL/h during training at 9°C, compared with 985 and 1209 mL/h for training and competition, respectively, in 25°C. Although sweat rates are likely to be lower in cold environments, other factors need to be considered.⁵ These include the wide interindividual variability in sweat response, variations in the intensity of training and player fitness, and the amount of insulated clothing worn during training, all of which will confound whether sweat rates and therefore fluid replacement are very different than in warmer conditions.

Previous evidence has found that children will not voluntarily drink adequate amounts of fluid when exercising in the heat.² In a study of 10- to 12-year-old boys, cumulative dehydration, core temperature, and end urine osmolality all increased during exercise in the heat when fluid consumption was voluntary compared with a fluid-administered trial.² By adolescence, it is proposed that youth sports players are more adept at consuming fluid at a rate comparable with adult competitors.⁶ There has also been speculation that fluid intake in cooler conditions may be insufficient without the pronounced thirst response that accompanies exposure to hot environments. However, the ratio of voluntary fluid intake to sweat loss during exercise is the same in the cold as it is in the heat.⁷

Hydration status can be determined according to objective noninvasive measures in the laboratory or subjective measurements.⁸ Laboratory measurements including measures of serum and urine osmolality, blood urea nitrogen, and hematocrit offer the most accurate means to assess hydration status but can be impractical and require specialized equipment. Urine osmolality is the most commonly reported measurement of hydration status, with values greater than 900 mOsm/kg used as an indicator of hypohydration.⁸ Noninvasive measures such as changes in body mass, fluid intake, and urine excretion offer simple, fast, and economical solutions, albeit with some loss of reliability in the accuracy of the measure. Changes in body mass are routinely measured in a club setting as an indicator of hypohydration and assume a linear relationship between the change in hydration status and body mass. Subjective measures of skin turgor, mucous membrane moisture, and thirst are less well reported. Currently, there is no accepted consensus on the best way to assess an individual’s hydration status.⁹

The hydration demand during physical exercise will depend in part on the climatic conditions to which the
athlete is exposed. Dehydration predominantly presents a thermoregulatory challenge; as skin blood flow is reduced during exercise and as plasma volume is depleted as sweat, this reduces heat dissipation and results in elevated core temperature.\(^\text{10}\) However, it has been suggested that dehydration of 1% to 2% body mass is tolerable in cold or temperate climates.\(^\text{11}\) Nevertheless, there is evidence that this level of dehydration may debilitate other aspects of sports performance, such as cognitive function.\(^\text{11-13}\) Equally important and often neglected is the observation that if a player commences training already hypohydrated, that player might not tolerate the 1% to 2% loss, and training performance might be impaired. A number of studies have found evidence of both youth and adult sports players exhibiting a tendency to begin training already in a hypohydrated state.\(^\text{6,14,15}\)

Another issue to consider regarding fluid requirements is information on the range of electrolyte losses in sweat for youth players, which is not well quantified. The main electrolytes include sodium and chloride ions, with small amounts of potassium, calcium, and magnesium ions. The loss of sodium has the greatest physiological implications, as it must be replaced to restore fluid balance and therefore has been the focus of much interest in the adult literature. Sodium concentration in adult sweat is typically within 40 to 60 mmol/L,\(^\text{16}\) with a range of 20 to 80 mmol/L.\(^\text{12}\) Depending on individual sweat rate, this can equate to losses of approximately 3 to 9 g NaCl in 90 minutes of elite-level football training in a hot environment.\(^\text{9}\) In addition, the concentration of potassium in sweat in adults is reported to be about 4 to 8 mmol/L.\(^\text{16}\)

Considering the number of participants in youth sports, there is surprisingly little information about the composition of their sweat during competition or training. In adolescent footballers (16–18 y), sweat sodium concentrations were reported as 55 ± 27 mmol/L, with average sweat losses of ~1540 mL/h in hot training conditions, which were similar to results observed in adults.\(^\text{17}\)

The aim of this study was to determine the hydration status, fluid intake, and electrolyte losses of professional male youth players training in a cool environment. To accomplish this, the hydration status before and after training, sweat rate, voluntary fluid intake, and electrolyte composition of players’ sweat were assessed.

## Methods

### Participant Information

Twenty-one male youth soccer players (age 17.1 ± 0.7 y, height 1.75 ± 0.05 m, body mass 69.2 ± 7.4 kg) who were members of a professional soccer academy in the southwest of England, UK, volunteered to participate in the study. The project was approved by the institutional ethics committee, and consent and assent forms were signed by parents and players, respectively.

All players were asked to maintain their normal daily lifestyle habits before the training and to follow their normal routines during the training session. On their arrival at the training ground, the anthropometric measurement of height was collected (Seca stadiometer SEC-225, Seca, Hamburg, Germany).

### Experimental Procedures

After the height measurement, the footballers were required to provide a urine sample for analysis. Urine color was assessed using a urine-color chart with a 1-to-8 scale (Dieticians in Sport and Exercise Nutrition, London, UK). Samples were analyzed for osmolality by freezing-point method on a bench-top osmometer (Gonotec Osmomat 030, Gonotec GmbH, Berlin, Germany). Immediately after voiding, subjects were weighed in minimal clothing (underpants) using digital scales (Hampel XWM 150K, Hampel Electronics Co, Taiwan; accurate to 50 g). Water bottles or other bottles containing sports drinks were weighed on a food scale (Salter Electronic Kitchen Scale, Slater Housewares Ltd, Kent, UK; accurate to 2 g).

Absorbent patches (Tegaderm Plus, 3M, 3M Healthcare, St Paul, MN) to collect the sweat were applied to the skin and positioned before the start of the training session. The absorbent gauze patches were covered with adhesive nonporous film to prevent evaporation of sweat. Skin sites were rinsed in deionized water and dried with clean electrolyte-free gauze pads. Patches were applied to the chest (pectoral), back (midscapula), thigh (lateral), and arm (triceps).

### Training Session

Subjects participated in a 100-minute training session combining training drills and simulated competitive matches that took place between 10:20 AM and noon on an outdoor grass playing field. Environmental conditions were dry, overcast, and typical of autumnal UK weather (temperature 11.0 ± 1.2°C, humidity 50% ± 3.3%, and wind speed 0.5–1.5 km/h) in the later part of the competitive football season (April). All measures and samples were collected and recorded onsite at the training ground and were designed to minimize disruption to the training session.

During training, subjects were encouraged to drink their normal fluid whether it was water or a sports drink and had access to their individual drink bottles on the side of the pitch. The players were supervised to ensure that they did not drink from other players’ fluid bottles and that they avoided spillage. If a player needed to use the toilet, body-mass changes were recorded. Six players passed urine during the training session. All wore the typical football training kit—boots, shorts, shirts, and tracksuit tops.

After the training session, absorbent patches were removed with forceps to avoid contamination, placed in empty salivette centrifuge tubes (Sarstedt), and stored at 4°C. For analysis, the salivette tubes were centrifuged at 10,000 g for 10 minutes to expel the sweat from the patch. Sweat was diluted 1000-fold in ultrapure water and...
analyzed by flame-emission spectroscopy to determine sodium and potassium ion concentrations, then diluted 100-fold and analyzed by atomic-absorption spectrophotometry for magnesium ion concentration, in a Pye SP9 series atomic-absorption/flame-emission spectrophotometer (Pye Unicam Ltd, Cambridge, UK). Values were obtained by plotting absorbance against a standard curve derived from 4 concentrations of known amounts. It was not possible to analyze 2 players’ sweat samples due to too low a sample volume, so all sweat analyses were conducted on a sample of 19 players.

Players then had their body mass measured and provided a second urine sample. Total fluid loss was calculated as body sweat loss plus urinary output minus total fluid intake. Sweat volume was calculated from the changes in body mass (corrected for the fluid intake) and urine volume. Unfortunately, 2 posttraining urine samples were spoiled during transportation to the laboratory, so all osmolality analyses were completed on 19 players.

Statistics
A priori, based on published literature with urine osmolality as the primary outcome measure, we estimated that a sample size of 28, based on a moderate effect size of .5, an alpha level of .05, and a power of .9, would be required. All data were tested for normality of distribution and are presented as mean ± SD. The statistical significance of pretest and posttest changes as a consequence of training was assessed using a within-subjects repeated-measure ANOVA with the inclusion of η² to estimate effect sizes. In order to determine magnitude-based inferences, the ±90% confidence intervals (CI) of the effect values were calculated according to Batterham and Hopkins.18 Pretest–posttest differences for mean values of body mass and urine osmolality were assessed using 90% CI and the chance that the differences represented substantial change (positive or negative). The quantitative chances that differences between pretraining and posttraining periods were qualitatively assessed as proposed by Hopkins19: 1% unlikely, 5% to 25% possible, 25% to 75% likely, 75% to 95% very likely, 95% to 99% almost certain. Correlational analyses using Pearson product–moment correlations (±90% CI) are also provided. A Wilcoxon signed-rank test was used to determine significance between pretraining and posttraining urine color. Significance for all statistical tests was set at the P < .05 level. All data were analyzed using the statistical package SPSS for Windows, version 15 (SPSS Inc, Chicago, IL).

Results
Table 1 provides the mean (SD) body mass, urine and sweat losses, sweat rate, and fluid intake during training. Pretraining body mass was significantly different from posttraining body mass (69.2 ± 7.4 kg and 68.8 ± 7.2 kg, P < .0001, η² = 0.48). The mean difference between pretraining and posttraining was 0.4 kg (90% CI 0.23–0.49 kg); the difference is likely to be very trivial. Mean fluid intake was 807 ± 557 mL (range 0–1700 mL).

Hydration Status
Mean urine color did not change significantly from pretraining to posttraining, 4 ± 1 to 4 ± 2 (Z score = –1.5 P = .14). Pretraining and posttraining urine osmolality were 1319 ± 525 and 687 ± 389 mOsmol/kg, respectively, and decreased significantly during training (N = 19, P = .001, η² = 0.47). The difference in the change in osmolality measurements pretraining to posttraining was 632 mOsmol/kg (350–910 mOsmol/kg); the difference is almost certainly a substantial one. Pretraining urine osmolality was significantly correlated with pretraining urine color (N = 19, r = .52 [CI .09–.79], P = .02), and posttraining urine was significantly correlated with posttraining urine color (N = 19, r = .62 [CI .23–.84], P = .005). Fourteen players provided pretraining urine samples with an osmolality greater than 900 mOsmol/kg, but only 4 of these players remained hypohydrated at the end of the training session.

Fluid Demands (Sweat Lost From Training Session)
There was no significant correlation between the change in osmolality and sweat loss (N = 19, r = –.39 [CI -.72 to .08], P = .10). There was no significant correlation between pretraining urine osmolality and fluid intake (N = 21, r = .27 [CI -.18 to .63], P = .23), as shown in Figure 1.

Body-Mass and Sweat Loss
Fluid intake and sweat loss were highly correlated (N = 21, r = .82 [CI .60–.92], P = .0001), as represented in Figure 2. The mean level of dehydration after the training session was completed was 0.5% ± 0.5%. The estimated sweat loss (corrected for the amount of fluid consumed) was 1.17 ± 0.66 L, and this corresponds to a mean sweat rate of 0.70 ± 0.40 L/h. In total, participants replaced 46% ± 88% of sweat lost during training.

Table 1 Body Mass (BM), Urine, and Sweat Losses and Fluid Intake During Training (N = 21)

<table>
<thead>
<tr>
<th>Pre BM (kg)</th>
<th>Post BM (kg)</th>
<th>BM loss (g)</th>
<th>Urine loss (g)</th>
<th>Fluid intake (g)</th>
<th>Sweat loss (g)</th>
<th>Sweat rate (L/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 69.2</td>
<td>68.8</td>
<td>364</td>
<td>20.7</td>
<td>807</td>
<td>1167</td>
<td>0.70</td>
</tr>
<tr>
<td>SD 7.4</td>
<td>7.2</td>
<td>383</td>
<td>7.0</td>
<td>557</td>
<td>662</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Figure 1 — Relationship between pretraining urine osmolality and fluid intake during training.

Figure 2 — Relationship between volume of fluid consumed during training and amount of sweat loss.
Electrolytes in Sweat

The mean electrolyte sweat concentrations measured during training (N = 19) for Na⁺, K⁺, and Mg²⁺ were 67.7 ± 21.7, 5.4 ± 2.8, and 0.6 ± 0.1 mmol/L, respectively. However, it was noted there were 2 outliers for the Na⁺ and K⁺ mean concentrations due to incomplete data points. Data without the outliers resulted in mean values of 67.8 ± 11.7 and 5.2 ± 1.1, respectively. There were no significant correlations between sweat loss and sweat concentrations of Na⁺ (r = −.11 [CI −.54 to .36], P = .67) or K⁺ (r = .14 [CI −.34 to .56], P = .58), but a significant correlation with Mg²⁺ was found (r = −.58 [CI −.79 to −.25], P < .009). There was no statistically significant correlation found between mean sweat rate and mean sweat sodium (r = −.11 [CI −.82 to −.17], P > .67) or potassium (r = .14 [CI −.34 to .56], P > .58).

Discussion

The results of this observational study provide descriptive data on hydration status before training and fluid intake and sweat and electrolyte losses in professional youth soccer players during a standard training session in cool conditions. The main findings were that despite the observation of players commencing training in a hypohydrated state, they were able to euhydrate during the actual training practice. In addition, there were wide variations in fluid intake and sweat rates and a lack of significant correlations between sweat rates and sweat electrolyte concentrations.

Urine color did not change between pretraining and postraining measures, yet urine osmolality was significantly reduced. This corroborates the conclusions of Armstrong et al.²⁰ that urine osmolality is more sensitive to change and should be preferred when accurate assessment is necessary. In the absence of sophisticated laboratory techniques, urine color can be employed as a qualitative index of hydration status but is not sensitive to changes in osmolality within a 2-hour training period under cold conditions. Given the trivial magnitude of change in this cool environment and time-limited capacity, urine color might be more useful as a one-off measure rather than a series of measurements. Dark urine indicates a fluid deficit, and pale yellow indicates insufficient hydration.²¹ with urine colors >3 having been shown by a number of authors to be of practical use to indicate dehydration.²⁰,²² Therefore, although it is a practical tool to use with soccer players, if interpretation is to be applied from pretraining to postraining measures, then caution is warranted.

Fourteen players provided pretraining urine samples with osmolality values greater than 900 mOsm/kg. Shirreffs and Maughan²³ have determined in adults that this approximates greater than 1.9% dehydration measured by body-mass loss, thus indicating that they are mildly hypohydrated before training. In adult athletes this is not uncommon; a third of elite soccer players exhibited similar symptoms of hypohydration before training²⁴ in conditions similar to those found in the current study. The prevalence in youth players is currently unknown and more data is required. The mean pretraining osmolality was 1264 mOsm/kg (N = 21), a value that would be comparable to induced dehydration from fluid restriction.²¹ It was encouraging that of the 14 players who commenced training hypohydrated only 4 players remained so after training. This number and magnitude of change we interpret to be a real and meaningful effect. However, based on a single training session, any implications should be interpreted cautiously and further replication is required. It is possible, for example, that values obtained from the bench-top osmometer could be skewed at these ranges, as calibration curves are typically generated between 300 and 850 mOsm/kg. Furthermore, samples were collected in the clubhouse rather than on waking. There may also be preexercise anticipatory mechanisms that suppress renal activity, which would lower the water content of urine. Nonetheless, these data are indicative of some players arriving in a hypohydrated state, as reconfirmed by a mean urine color of 4 on the urine chart, indicating mild hypohydration. These figures are similar to those in 2 other studies where 50% to 75% of soccer players at a summer camp were observed to be hypohydrated at the start of each day’s training session.²⁴,²⁵ In the only other study examining youth hydration status, 17 of 20 elite male Brazilian soccer players (mean age 17.2 ± 0.5 y) were found to have begun training in a hypohydrated state according to urine specific gravity measurement (USG > 1.02). This observation was repeated in the next 2 consecutive training days, although they occurred in a tropical environment (26.3–34.4°C, relative humidity 40–85%).²⁶ It has been suggested by some researchers²⁷ that adults with the highest pretraining urine osmolality are more likely to drink more during training. In our youth players, this was not found to be the case (Figure 1), a finding also reported by Silva et al.²⁶ It is possible that the differing water and sports drinks consumed by the players contributed to differing stimulus to consume their drinks. Equally, the observed hypohydration experienced by the players was probably not sufficient to stimulate the thirst mechanism to drink. More research is required to determine hydration status in youth players, the extent to which these are acute or chronic observations, and their effect on training performance.

A significant relationship was observed between fluid intake and sweat loss (Figure 2). Numerous factors will influence fluid ingestion, including individual behavior of the players, opportunities to drink and access to drinks bottles, and perceived sweat loss due to training. The sweat rate of 0.7 L/h was comparable to findings by Broad et al.²⁴ of adolescent soccer players training in a cold (9°C) environment. This is less than the sweat rate reported in elite adult male footballers with a mean sweat rate 1014 ± 270 mL/h, despite training in even colder conditions (5°C).²⁴ This is likely attributable to a variety of factors such as maturation and the intensity of the training session or training status, both of which affect sweat response to exercise. However, it should be acknowledged that even when these factors (intensity and fitness) are
held constant, there is still large interindividual variability in sweat rate and sweat composition.28

The fluid lost due to exercise equated to a gross dehydration percentage loss in body mass of 0.5%, and although this is statistically significant, it is a negligible value in hydration terms and easily tolerated by young athletes. This qualitative “negligible or trivial change” judgment of the magnitude-based inferential approach demonstrates pertinently that despite the statistically significant mean pre–post body-mass change, individual variability likely precludes establishing meaningful inferences about this observed magnitude of change. This could be improved by increasing the sample size to reflect greater representation of youth soccer players per se. Although the sample size is similar to that in some previously published studies under hot and cold conditions, this sample was representative in the sense that it included all players currently contracted to the youth academy. However, it is acknowledged that this type of opportunistic sampling would require greater subject numbers to conclusively comment on changes in body mass in cold conditions. Although it has been suggested that dehydration during exercise is tolerable up to 2% body weight,11 this assumes that players begin training euhydrated. As it was observed that a number of players were hypohydrated at the onset of training, this could augment the dehydration to a theoretically greater state at the end of training. It is acknowledged that in cool weather the risk of heat injury is significantly reduced, but, of course, what is unknown is the effect of this repeated behavior on training performance. Experimentally, deliberately hypohydrating young people and then have them perform exercise may pose significant ethical barriers, so characterizing this phenomenon in the field may be the most appropriate way to investigate. Irrespective of these concerns, even if there is no requirement for fluid and electrolyte replenishment during training or competition, there is a case for administering doses of easily absorbable carbohydrate via fluid that will benefit the players.10

Sweat sodium and potassium concentrations were similar in the adolescent boys in the current study to those of adults investigated previously.27,29 However, to the best of our knowledge there are no published values on sweat sodium, potassium, and magnesium in cool conditions for children or adolescents. Replacement of electrolytes is considered important, particularly in hotter environments and especially during the recovery period from training.16,30 Although it is accepted that sodium is the most crucial electrolyte in fluid recovery after training, followed by potassium, the role of magnesium is unclear, and it has not been considered necessary to include in sports drinks. This study provides descriptive normative data on what physiologists can expect to observe under training conditions. However, because of the small measurements of magnesium in sweat, more replication of this variable is needed. The light energy absorption for magnesium at a 1:100 dilution was discrete in our samples, so the mean value of 0.6 (0.1) mmol/L needs to be treated with caution. A dilution of 1:10 is advised to increase the signal amplitude in sweat samples for a more sensitive determination of magnesium that may confirm these values.

An interesting observation in this study was the ability of most of the participants to voluntarily rehydrate during exercise, replacing 46% of the fluid lost during training. However, the high standard deviation, which is double the mean replacement percentage figure, highlights the wide interindividual differences. The distribution of the fluid-replacement data showed that it was negatively skewed. This is not uncommon—elite adult male athletes have been reported to replace only 25% of fluid loss in a cool environment27 and 47% in a warm environment.14 The rate of fluid consumption is likely to be influenced by a “Hawthorne effect” whereby the participants are aware their drinking was being measured. A consequence of the effect on behavior in replacing fluid is that the postexercise urine osmolality was significantly lowered than preexercise. This lowering in osmolality was despite a net decrease in fluid balance, which may indicate diuresis accompanying the effort to rehydrate. However, we feel that the Hawthorne effect explains only a part of the real-life situation because players were not affected sufficiently to alter the types of drinks they brought to the ground and subsequently consumed. The Hawthorne effect did not appear to influence 3 boys who reported they never brought drinks to training and rarely drank during training sessions. Our presence at the training was not so impactful that it influenced their behaviors and altered them. These results and observations highlight the importance of being cautious in advocating that a fixed volume be drunk by each squad player, because interindividual behaviors are so diverse.

One of the key practical findings in this study is the confirmation of the large variability in pretraining hydration status; consequently, the advice or guidelines provided to youth competitors and their coaches cannot be universal. It would appear there was a real effect of some players in neglecting their fluid consumption before a training session. Therefore, monitoring hydration status would be recommended, if only to identify the most vulnerable soccer players. This practice can be performed by assessing the first urine of the day with the urine-color chart before arrival at the training ground. While the sweat lost as a result of the training may not be sufficient to impair performance, it could augment existing dehydration processes, which if continuously repeated could prove detrimental to the player’s performance. Therefore, while fluid consumption has predominantly been emphasized during and after training, part of the players’ education should also stress the importance of pretraining hydration. It should not, however, be taken for granted that knowledge of hydration practices will necessarily translate into immediate change in behavior.14 As Decher et al24 found in their study, knowledge alone of young soccer players was not enough to translate into implementing effective hydration strategies. Therefore, the coaching/sports-science team must be proactive in their approach.
Conclusion

In conclusion, the fluid intakes and sweat rates of the adolescent soccer players during a training session in cool conditions were found to be similar to those of other studies in warmer conditions.4–7,10–14 Previous observations from adult athletes being hypohydrated before training seem likely to be confirmed in youth players, although opportunities to drink during scheduled breaks in training and coaches reminding players to drink appear to have been successful in reestablishing euhydration in most of the players. Measurements of urine color pretraining and posttraining, although significantly and positively correlated to urine osmolality, did not adequately reflect players’ changing hydration status and must be used with caution. Therefore, it is important for coaches and sports-science support staff to be aware of adequate hydration before training, as well as appreciating the potential for significant fluid loss by some players training in cool environments.

Acknowledgments

This study was supported by a grant from the GlaxoSmithKline Consumer Healthcare R&D, Slough, UK. We would like to thank Mr Simon Hayward, academy director, and all the players for their involvement, as well as Lex Mauger, Thomas Radtke, and John Truelove for their assistance in data collection.

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