Factors influencing hydration status during a National Collegiate Athletics Association division 1 soccer preseason

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Abstract:

Objectives: To investigate the roles that training load and environmental conditions have on fluid balance during a collegiate men's soccer preseason. **Design:** Observational study. **Methods:** Twenty-eight male collegiate soccer players (mean ± SD; age, 20 ± 1.7 y; body mass (BM), 79.9 ± 7.3 kg; height, 180.9 ± 6.8 cm; body fat, 12.7 ± 3.1%; VO_{2max}, 50.7 ± 4.3 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in this study. Prior to (PRE) and following (POST) each team session, BM, percent BM loss (%BML) and hydration status was measured. Participants donned a heart rate and GPS enabled monitor to measure training load. For all team activities, ambient temperature (T_{AMB}) and relative humidity (RH) were obtained from the nearest local weather station. Participants consumed 500 mL of water as part of the team-based hydration strategy before and after training session. Stepwise linear regression was used to identify the variables that predicted %BML. Significance was set a-priori $p < 0.05$. **Results:** Total distance covered predicted %BML during all preseason activities ($r^2 = 0.253$, $p < 0.001$), with T_{AMB} and RH further adding to the model ($r^2 = 0.302$, $p < 0.001$). %BML never exceeded 2% of BM during any one session and daily variation in BM was <1% from baseline measures. Urine specific gravity was greater than 1.020 on 12/15 days and U_{COL} was above 4 on 13/15 days, indicating a state of hypohydration. **Conclusions:** Total distance covered was the best predictor for the extent of body water losses during a collegiate preseason. While the team-based hydration strategy during preseason was successful in minimizing fluid losses during activity, participants arrived hypohydrated 80% of the time, necessitating a greater focus on daily fluid needs.

Keywords: Fluid regulation | Dehydration | Body mass loss | Ambient temperature | Training load

Article:

Practical implications

- Total distance covered influences on %BML, but the environmental conditions had a negligible role during soccer preseason.
- As athletes cover greater distances in training sessions and matches, especially during hot and humid environmental conditions, sports scientist, sport medicine staff, and coaches should increase fluid availability and encourage hydration during and following sessions.
- Team-based hydration strategies may be a useful tool to minimize fluid losses during session and assist in recovery of fluid losses from previous activities.
- It is important not only to monitor fluid losses during session and day-to-day body mass variation but also chronic hydration state.
- Sports scientist, sports medicine staff, and coaches should continue to work with athletes to find strategies to improve their chronic hydration state.

1. Introduction

During sport and physical activity, maintaining an appropriate fluid balance is a vital component when considering optimizing exercise performance. Exercise induced dehydration exacerbates both cardiovascular[1] and thermoregulatory strain.[2] Evidence supports that dehydration exceeding 2–2.5% of body mass (BM) loss adversely affects aerobic exercise performance,[3, 4] cognitive performance,[5] and strength and power performance,[6] while 2–3% BM loss also impairs technical skills in soccer.[7] To mitigate dehydration-induced deficits in exercise performance, current recommendations suggest a euhydrated arrival to physical activity, minimizing fluid losses during activity based on individual fluid needs, and replacing remaining losses following exercise.[3, 8] Given the given the variability in sweat rate between individuals during exercise, developing hydration strategies based on individual need lends to improved performance versus fluid consumed ad libitum.[4, 9]

Given the documented variability in individual sweat rates (0.3–2.5 L/h), the physical demands of the differing field positions and the infrequent opportunities to drink during soccer match play, the risk of hypohydration (>2% body mass loss) is quite prevalent, especially in those with high sweat rates.[7] In addition, evidence also shows that athletes are often inadequately hydrated prior to the start of activity,[10, 11] which when coupled with reduced opportunity to consume fluids during match play, prevent the athlete from being able to correct the fluid deficit during activity.[15] These concerns may be further magnified depending on time of the year and playing season when training loads and environmental conditions may predispose athletes to increased risk of dehydration.

An athlete's sweating response is altered by exercise intensity, volume, and environmental conditions.[12] As demonstrated in a lab study, exercise intensity independently increased sweat sensitivity.[13] In professional soccer players, greater sweat losses and overall magnitude of dehydration was greater when athletes performed high intensity exercise or performed game simulation exercise during exercise in the heat.[14] While previous literature has shown the relationship between exercise intensity and heat stress on fluid loss in soccer, no known literature has investigated the effects of training load and environmental conditions over the course of multiple bouts of training in soccer. Therefore, the purpose of this study was to investigate the role that training load and environmental conditions had on fluid balance during a collegiate men's soccer preseason.

2. Methods

Twenty-eight National Collegiate Athletics Association (NCAA) Division 1 male collegiate soccer players (mean ± SD; age, 20 ± 1.7y; body mass (BM), 79.9 ± 7.3 kg; height, 180.9 ± 6.8 cm; body fat, 12.7 ± 3.1%; VO_{2max}, 50.7 ± 4.3ml·kg^{-1}·min^{-1}) participated in this study, which took place during the 2016 National Collegiate Athletics Association men's soccer preseason. Following an explanation of the study procedures, of which was approved by the Institutional Review Board at <removed for review>, participants provided written and informed consent to participate. The duration of the study, which took place during preseason (August10 to August25) and included the first three days of the regular-season sessions was comprised of a total of 19 days. All days consisted of one-training session except for days 1, 2, and 7, in which two-training sessions were performed (data from day1 and day2 was corrected only from one training session). Preseason matches occurred on days 5 and 11, and regular-season matches occurred on days 17 and 19. Participants had a coach scheduled off/recovery-day on days 6, 12 and 18. Thus, data were collected from 17 total sessions.

Prior to each scheduled session participants provided a pre-session (PRE) body mass (BM) and urine sample for assessment of hydration status. Urine specific gravity (USG) measured using a handheld refractometer (Model TS400; Reichert Inc., Depew, NY) and urine color (U_{COL}) using a validated scale[15, 16] were used to assess hydration status with clinical thresholds indicating hypohydration being USG > 1.020 and U_{COL} > 4. BM measures were performed on an electronic scale measured to the nearest 0.1 kg (Defender 5000, OHAUS, Parsippany, NY) with participants wearing minimal clothing (i.e. shorts and shirts). Given the field-based nature of this study, types of foods and drugs/supplements consumed, which may influence USG and U_{COL} were not measured in this study.

Participants then donned a 10 Hz-a heart rate (HR) and global positioning satellite (GPS) and 200Hz-microelectromechanical-enabled player tracking device (Polar Team Pro, Polar Electro, Lake Success, NY), which has been shown accurate and reliable outdoors (unpublished data), to capture training load during each session. The training load metrics that were obtained were: session-time (ST), total-distance (TD), training load score (TLS), total-distance·session-time^{-1} (TD·ST^{-1}), average HR (HR_{AVG}), and average speed (SP_{AVG}). TLS, which is a proprietary algorithm developed by Polar, is based on training impulse[17] and it is further personalized by entering age, height, BM, maximum HR, resting HR, VO_{2max}, and training frequency, within the participant profile in Polar Team Pro.

Following PRE measures, participants consumed 500 mL of water before the start of training sessions as part of the team-based hydration strategy implemented by the coaching staff. During training sessions, participants had unlimited access to fluids in which they could consume at their own discretion in conjunction with scheduled water breaks throughout the training session. Environmental conditions of ambient temperature (T_{AMB}) and relative humidity (RH) were collected retrospectively using an online environmental-based server (www.weatherunderground.com) where average values for T_{AMB} and RH were calculated during session.

Following the completion of training sessions (POST), participants consumed an additional 500 mL of water as part of the team-based hydration strategy. Participants then provided a POST BM measure while wearing minimal clothing to calculate the change in body mass that had occurred during the training session. Since, the total volume of fluid consumed urine losses were not measured during the training sessions, the resulting change in body mass measured between PRE and POST BM represents the participants fluid deficit following training as sweat rate cannot be calculated.

Total body water deficit was measured by calculating a percentage of body mass loss: ([POST-BM − PRE-BM]/PRE-BM)*100.[18] In addition, changes in PRE-BM from day 1 of the season were measured and calculated as a percentage from baseline using the following equation: ([PRE-BM − baseline BM]/baseline BM)*100.

All statistical analyses were performed using SPSS (v.24. IBM Corporation, Armonk, NY). Data was reported as mean ± SD. Repeated measures ANOVA with subsequent post-hoc analyses for multiple comparisons using the Bonferroni adjustment were used to assess changes in PRE-BM, %BML, %PRE-BM change from baseline, and environmental conditions. Step-wise linear regression analysis was used to predict %BML from training load metrics, T_{AMB}, and RH. Paired t-test was performed to examine the difference in %BML and TD between training session and match. The coefficients of variation (CV) was calculated to measure reliability. Significance was set at $p < 0.05$.

3. Results

Throughout the preseason training period, the mean training loads were: ST, 128 ± 46 min; TD, 5888 ± 2059 m; TLS, 167 ± 60 au; TD ST^{-1}, 46 ± 4.8 au; HR_{AVG}, 132 ± 8 bpm; and SP_{AVG},3.0 ± 0.3 $m{\cdot}s^{-1}$. Table 1 depicts the changes in BM, %BML, %PRE-BM and number of participants arriving hypohydrated to each training session. There were small fluctuations of PRE-BM on each day, but daily variations in PRE-BM did not exceed 1% regardless of %BML of previous session. Moreover, %BML never exceeded 2% during any one session. Despite the minimal changes in fluid loss during or between training sessions, USG exceeded 1.020, and U_{COL} exceeded 4, indicating hypohydration, on 12/15 (80%) and 13/15 (87%) of days, respectively (Fig. 1). %BML during match play (−1.3 ± 0.7%) was significantly greater than during training session (−0.8 ± 0.4%, $p < 0.001$). TD in matches (9242 ± 3108 m) was also significantly higher than in training sessions (5114 ± 779m, $p < 0.001$).

An increase in TD significantly predicted %BML during preseason ($r^2 = 0.253$, $p < 0.001$) (Fig. 2). When including T_{AMB} and RH into the model, the prediction of %BML was strengthened ($r^2 = 0.302$, $p < 0.001$), however, neither T_{AMB} ($p = 0.57$) or RH ($p = 0.75$) (or in combination, $p = 0.89$) did not significantly predict of %BML ($p > 0.05$). All other training load metrics, ST ($p = 0.11$), TLS ($p = 0.70$), TD ST^{-1}($p = 0.23$), HR_{AVG} ($p = 0.81$), and SP_{AVG} ($p = 0.59$) were not significant predictors of %BML.

Table 1. BM measurements and the environmental conditions throughout a preseason session.

Session	PRE BM (kg)	%BML (%)	%PRE BM change (%)	T_{AMB} (°C)	RH (%)	# of participants with USG > 1.020
1	80.4 ± 7.2	−0.4 ± 0.8	0 ± 0	19.8	70.7	14
2	80.3 ± 7.4	−1.0 ± 0.9[a]	−0.1 ± 0.9	21.4	88.9	10
3	80.9 ± 7.3	−0.7 ± 0.7	0.5 ± 1.1	25.9	52.7	11
4	80.7 ± 7.1	−0.3 ± 0.7	0.4 ± 1.1	22.6	60.3	14
5	80.9 ± 7.3		0.7 ± 1.1			7
6	80.8 ± 7.3	−1.0 ± 0.8	0.5 ± 1.3	23.3	78.0	9
7	80.7 ± 7.2	−0.5 ± 0.7	0.3 ± 1.3	28.3	60.2	13
8	80.8 ± 7.3	−0.9 ± 0.6	0.5 ± 1.4	23.9	76.7	13
9	80.9 ± 7.2	−1.0 ± 0.5[a]	0.6 ± 1.4	24.1	79.0	12
10	80.8 ± 7.4	−1.0 ± 0.6[a]	0.5 ± 1.4	25.0	76.6	10
11	80.9 ± 7.3	−1.5 ± 0.8[a]	0.5 ± 1.8	24.3	74.5	9
12	80.2 ± 7.1	−1.0 ± 0.6	−0.3 ± 1.4	27.2	56.0	9
13	80.3 ± 7.0	−1.3 ± 0.6[a]	−0.1 ± 1.7	22.2	80.2	15
14	80.3 ± 7.1	−0.6 ± 0.6	−0.1 ± 1.9	22.2	89.0	15
15	80.7 ± 7.2	−0.3 ± 0.6	0.3 ± 2.2	23.4	84.3	11
16	80.3 ± 7.4	−1.1 ± 0.9	−0.2 ± 1.8	22.4	55.8	9
17	80.8 ± 7.0	−1.4 ± 1.0[a]	0.5 ± 2.1	21.2	63.0	
Team Ave	80.6 ± 0.3	−0.9 ± 0.4	0.3 ± 0.3	23.6	71.6	
CV (%)	0	−42	123	9	17	

[a] Indicates significant difference from session1.

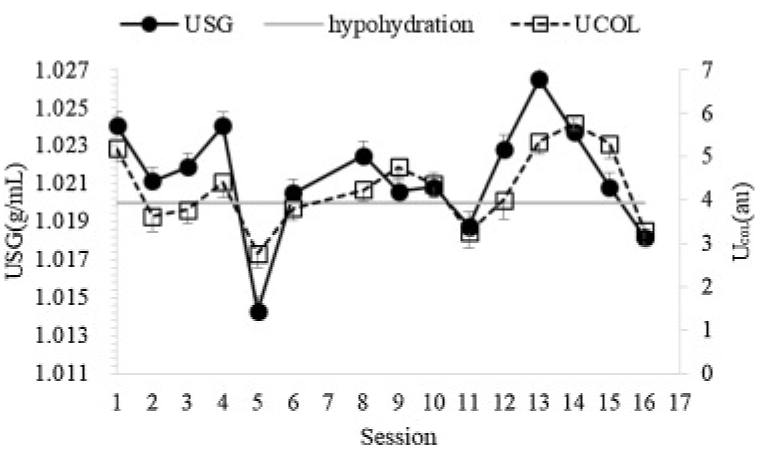

Figure 1. Changes in USG and U_{COL} throughout the collegiate men's soccer preseason training period. The gray line depicts the clinical threshold for hypohydration. USG = Urine Specific Gravity, U_{COL} = Urine Color.

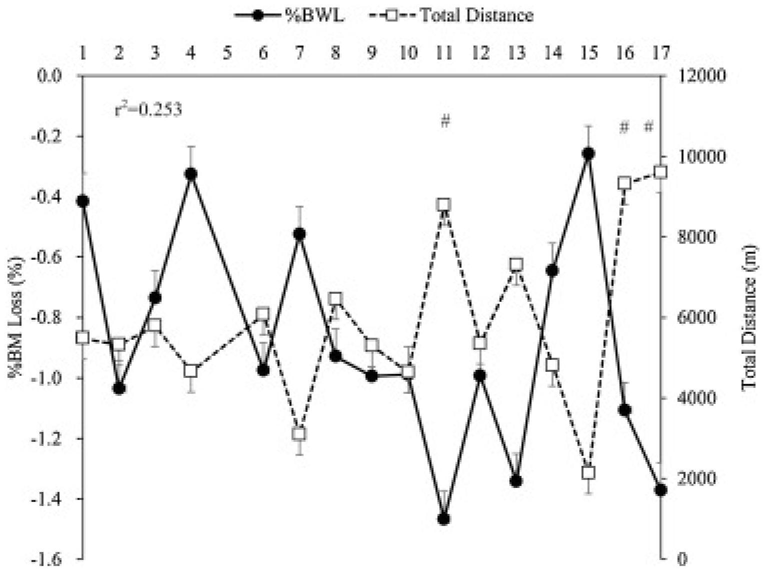

Figure 2. Relationship between %BML and total distance. # indicates a team session where a match was played (%BML was not able to be collected at the match on session 5).

4. Discussion

The purpose of this study was to investigate the role that training load and environmental conditions had on fluid balance during a collegiate men's soccer preseason. The current study found that the TD covered during a preseason training session accounted for 25% of the variance in %BML. While the addition of T_{AMB} and RH accounted for an additional ~5% of the variance in %BML, the environmental conditions that the participants were exposed to during preseason did not significantly influence the degree of body water losses. Understanding the influence that training load and the environmental conditions has on %BML during a collegiate soccer preseason can further assist athletes, coaches, medical personnel, and strength and conditioning staff in optimizing individualized and team-based hydration strategies to mitigate risk of heat-related illness and maximize performance.

The findings from this study suggest that even though %BML and PRE-BM measures varied throughout the preseason, daily variation never exceeded 1% of baseline BM measures and participants never exceeded 2%BML from water losses during any one training session. Cheuvront et al. showed that when physically active males replaced 100% of sweat losses following exercise, day-to-day BM variability was less than 1%.[18] Other literature has shown that over consecutive days of preseason training, fluid deficits were compounded, leading to greater levels of hypohydration.[19] Given that the participants in our study arrived at each session within 1% BM, it is likely that they were successful in replacing daily water losses ahead of the next day's training session.

While the variations of daily BM and end session %BML was minimized, measures of USG (1.021 ± 0.002) and U_{COL} (4 ± 0) showed that participants arrived hypohydrated for most days (80% and 87% based on USG and U_{COL}, respectively) of preseason training. Our findings coincide with previous literature that shows the commonality of athletes starting exercise in a hypohydrated state.[10, 20, 21] This could be due to a multitude of factors, however, it is postulated that athletes lack the appropriate knowledge regarding appropriate fluid intake.[22] In addition, unlimited access to fluids and the constant reminders for athletes to minimize their fluid during activity may not translate to every-day life outside of sport, thus predisposing athletes to a constant state of hypohydration if they are not consuming daily recommended volumes of water.[23]

In general, voluntary dehydration is widely admitted during exercise when athletes have free access to fluid, which can negatively influence performance.[24, 25, 26] In the current study, participants were required to consume 500 mL of water before and after every training session in addition to having unlimited access to water during exercise. This team-based hydration strategy kept the average overall water losses to <2% of BM across our participants and it appeared to be effective in mitigating some of the fluid losses in a population experiencing a high training demand.

%BML during match play was significantly higher compared to the training sessions even though the extent %BML was less than 2% of BM in both exercise scenarios. One reason for this was due to larger TD covered in matches (MD = 4128 m). In addition to this, soccer match play inherently reduces the availability of fluids during the match, which only allows athletes the opportunity to consume fluids before, during half time and following the match. This may explain why our participants exhibited greater fluid losses as compared to a training session where fluid is available ad libitum throughout exercise. It must be acknowledged that individual fluid needs vary based on one's sweat rates, therefore, it is imperative that during match play, a hydration strategy that minimizes fluid losses of all athletes must be established.

In the current study, total distance covered during a bout of physical activity was the most predictive of %BML. This could be because greater workloads lend to an extended period of time in which sweat production for the dissipation of metabolically produced body heat, which subsequently increases the volume of body water lost from the body in the form of sweat.[27] The environmental conditions that the participants were exposed to had little effect on predicting %BML following a bout of physical activity. While environmental conditions may dictate the capacity and mode in which the body dissipates stored body heat, the minimal changes in environmental conditions in the current study may not have influenced the body's normal thermoregulatory response to exercise.[27]

This study is not without limitations. The amount of fluid consumed ad libitum and urine during training session were not measured, except the 1L that was consumed for the team-based hydration strategy. Also, the team did not have a hydration strategy during matches and fluid intake was not monitored. Monitoring the amount of fluid intake may provide more detailed information regarding hydration (i.e., if fluid intake was matched to sweat rate). Also, baseline BM which was used to calculate %PRE BM change from baseline was a single measure on the first day of preseason. A 3–5 day measurement period would be needed to get a baseline BM and hydration state in individuals. Lastly, types of foods and drugs/supplements consumed were not measured in this study.

5. Conclusions

In conclusion, TD, T_{AMB}, and RH were predictive of %BML during preseason in a collegiate male soccer. However, TD accounted for the highest variability of body water losses and environmental conditions had a negligible role in predicting the extent of dehydration. Furthermore, %BML never exceeded 2% of BM on any given session during the preseason period. Additionally, participants arrived without major BM deficits from the previous day's session, as day-to-day BM fluctuations were within 1%. Thus, this team-based hydration strategy was successful in minimizing fluid losses during training sessions and ensuring minimal variation from day-to-day BM measures. However, these participants were in a chronic state of hypohydration given their daily pre-session urine measures. Therefore, participants minimized their fluid losses successfully during preseason based on the team's strategy, however, future research should consider strategies to assist athletes in achieving a state of chroic euhydration.

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