# Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment

**Jennifer C. Gibson, Lynneth A. Stuart-Hill, Wendy Pethick, and Catherine A. Gaul**



**Abstract:** Dehydration can impair mental and on-field performance in soccer athletes; however, there is little data available from the female adolescent player. There is a lack of research investigating fluid and electrolyte losses in cool temperatures. Therefore, the purpose of this study was to investigate the pretraining hydration status, fluid balance, and sweat sodium loss in 34 female Canadian junior elite soccer athletes (mean age ± SD, 15.7 ± 0.7 years) in a cool environment. Data were collected during two 90 min on-field training sessions (9.8 ± 3.3 °C, 63% ± 12% relative humidity). Prepractice urine specific gravity (USG), sweat loss (pre- and post-training body mass), and sweat sodium concentration (regional sweat patch method) were measured at each session. Paired *t* tests were used to identify significant differences between training sessions and Pearson's product moment correlation analysis was used to assess any relationships between selected variables ($p \leq 0.05$). We found that 45% of players presented to practice in a hypohydrated state (USG > 1.020). Mean percent body mass loss was 0.84% ± 0.07% and sweat loss was 0.69 ± 0.54 L. Although available during each training session, fluid intake was low (63.6% of players consumed <250 mL). Mean sweat sodium concentration was 48 ± 12 $mmol \cdot L^{-1}$. Despite low sweat and moderate sodium losses, players did not drink enough to avoid mild fluid and sodium deficits during training. The findings from this study highlights the individual variations that occur in hydration management in athletes and thus the need for personalized hydration guidelines.

*Key words:* hydration, soccer, adolescent, female, sweat sodium, fluid balance.

**Résumé :** La déshydratation est nuisible à la performance mentale et physique sur le terrain chez les athlètes au soccer; néanmoins, il y a peu de données disponibles au sujet des joueuses adolescentes. Cette étude se propose donc d'analyser avant un programme d'entraînement le statut d'hydratation, l'équilibre hydrique et la perte de sodium dans la sueur chez 34 jeunes joueuses de soccer de niveau élite au Canada (âge moyen ± écart type, 15,7 ± 0,7 ans) dans un environnement frais. On recueille les données au cours de deux séances de 90 min d'entraînement sur le terrain ((9,8 ± 3,3 °C, 63 ± 12 % HR (humidité relative)). Avant chacune des séances, on mesure le poids spécifique de l'urine (USG); on évalue la perte de sueur durant la séance (masse corporelle avant et après la séance) et la concentration de sodium dans la sueur (analyse des tampons appliqués sur des régions de l'organisme). On utilise des tests t pour mesures appariées afin d'identifier les différences significatives et les coefficients de corrélation de Pearson pour déterminer les relations entre des variables sélectionnées ($p \leq 0{,}05$). Quarante-cinq pour cent des joueuses se présentent à la pratique dans un état de déshydratation (USG > 1,020). La perte moyenne de masse corporelle est de 0,84 ± 0,07 % et la perte de sueur, de 0,69 ± 0,43 L. Même disponible durant les séances d'entraînement, l'apport de liquide est faible : 63,6 % des joueuses boivent moins de 250 mL. La concentration moyenne de sodium dans la sueur est de 48 ± 12 $mmol \cdot L^{-1}$. Même en présence de faible taux de sudation et une perte modérée de sodium, les joueuses ne boivent pas assez pour contrer un déficit hydrique et sodique au cours de la séance d'entraînement. Ces observations mettent en évidence les variations individuelles de la gestion de l'hydratation des athlètes et soulignent la nécessité d'élaborer des directives personnalisées en matière d'hydratation.

*Mots-clés :* hydratation, soccer, adolescent, femme, sodium dans la sueur, équilibre hydrique.

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## Introduction

The 2006 Fédération Internationale de Football (FIFA) "Big Count" Football Worldwide Survey revealed that 26 million women across 132 countries play soccer, with 405 000 female youth players (<18 years old) registered in Canada (FIFA Big Count 2006). Soccer is a high intensity, intermittent sport (Rosenbloom et al. 2006). During training and competition, adolescent athletes are at risk of dehydration, a state that is known to negatively impact athletic performance (Casa et al. 2000; Sawka et al. 2007; Coyle 2004). Adolescents, who by definition are still physically maturing, may

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also be at increased risk for heat illness and dehydration because of underdeveloped and less efficient thermoregulation and thirst mechanisms (Iuliano et al. 1998; Rosenbloom et al. 2006). Careful attention to hydration is therefore needed to support optimal training and game performance (Rosenbloom et al. 2006).

Dehydration in adult male and female soccer players has been associated with elevations in core temperature (Ali et al. 2011; Edwards et al. 2007), heart rate (Ali et al. 2011), lactate production (Ali et al. 2011), ratings of perceived exertion (Ali et al. 2011; Edwards et al. 2007), as well as a reduction in soccer-specific skills and mental test performances (Edwards et al. 2007). Hydration research to date has shown that soccer athletes do not optimally replace fluids lost during training (Broad et al. 1996; Shirreffs et al. 2005; Maughan et al. 2005; Kilding et al. 2009; Maughan and Shirreffs 2007), have higher sweat and electrolyte losses than nonathletes (Mao et al. 2001), and have higher sweat rates with increasing age (Mjaanes et al. 2006). Because of the demonstrated large interindividual variation of sweating responses and fluid intake habits, hydration recommendations should be unique to the individual player to offset dehydration (Petrie et al. 2004; Broad et al. 1996; Kilding et al. 2009; Maughan et al. 2005; Shirreffs et al. 2005). Despite the current growing body of evidence in male soccer players, there is little hydration assessment data in junior elite female athletes and even less in cool environments. The purpose of this study, therefore, was to comprehensively investigate the pretraining hydration status as well as the fluid balance and sweat sodium losses during training in Canadian junior elite female soccer athletes.

## Materials and methods

### Participants

A total of 34 (mean age ± SD, 15.7 ± 0.7 years) junior elite female soccer athletes participated in this study. Athletes were recruited from 3 age-group (U18 ($n$ = 6), U16 ($n$ = 12), and U15 ($n$ = 16)) teams playing at the highest regional competitive level in British Columbia, Canada. Following a full description and orientation to the study, informed consent from athletes and parents was obtained prior to any data collection after institutional research ethics approval from the University of Victoria's Human Research Ethics Board and Biosafety Committee. All participants completed hydration assessments; however, because of scheduling conflicts, 2 participants (U18 group) completed only 1 hydration assessment and 3 participants (U16 group) completed their second assessment on a training day separate from their group peers.

### Experimental design

A descriptive, cross-sectional research design was implemented. All athletes were part of a larger study, which also assessed nutrition status (Gibson et al. 2011). Participant hydration assessments were conducted during 2 typical, 90-min training sessions (T1 and T2) and were separated by 7 days. Participants were encouraged to maintain normal hydration practices throughout this period. Each participant completed a nutrition–hydration questionnaire where self-reported hydration habits (timing, type of beverage, and quantity) before, during, and after training sessions were recorded.

The laboratory in which all physiological data were collected was adjacent to the training field. Participants reported to the laboratory for hydration assessment approximately 30 min before each training session. Upon arrival, participants produced and collected a mid-stream sample of urine into a labelled urine collection container. Urine samples were analyzed for urine specific gravity (USG) within 30 min of collection (PAL 10s Pocket Refractometer, ATAGO Tokyo, Japan). Following urine collection, pretraining body mass (nude) and personal hydration container–water bottle mass were recorded in a private in-lab washroom using the same scale (AND FG-150K scale, to the nearest 0.02 kg). Athletes' preferred beverages were recorded during and after training. All participants were instructed to drink only from their own beverage containers and not to spit out fluid during training or use it for any other purpose other than hydration. Sweat sodium concentration was determined by using closed patch, regional sweat collection, a commonly used and valid method when assessing large numbers of participants in the field (Kilding et al. 2009; Maughan et al. 2005). Using the protocol outlined by Patterson et al. (2000), absorbent sweat patches (Tegaderm + Pad, 3M Neuss, Germany) were applied to the skin at 5 sites on the right side of the body (chest, scapula, forearm, thigh, and lower back).

During the training sessions, participants were instructed to return to the laboratory to collect any urine–feces voided. Mean heart rate (beats·min$^{-1}$) and percentage of predicted maximum heart rate ($HR_{max}$) (Fox et al. 1971) was measured for each athlete (Polar Team 2, version 1.1.0.3, Polar Systems, USA). Time spent in intensity zones relative to estimated $HR_{max}$ were categorized as very light (<35%), light (35%–54%), moderate (55%–69%), hard (70%–89%), and very hard (>90%) (Pollock et al. 1998). Ambient (dry) temperature and relative humidity were recorded at 15-min intervals throughout training sessions (QuestTemp 36, Thermal Environmental Monitor, Quest Technologies). The number of water breaks and training activities were observed and recorded throughout each training session. Fluid breaks were at the discretion of the coach and players and not actively influenced by the investigators.

Changes in body mass have been shown to accurately represent changes in body water (Baker et al. 2009). Immediately after soccer training, participants returned to the laboratory where body mass (nude, towelling off excess sweat) and water bottle mass were recorded (to the nearest 0.02 kg). Sweat loss was calculated as follows (assuming 1 kg = 1 L):

$$\text{sweat loss} = (\text{pre-body mass} - \text{post-body mass}) + (\text{fluid intake} - \text{urine output})$$

where sweat loss, fluid intake, and urine output were measured in litres (L), and body mass measured in kilograms (kg). Percent body mass (kg) was calculated as described by the following equation:

$$\%\text{body mass loss} = (\text{pre-body mass} - \text{post-body mass})/\text{pre-body mass} \times 100$$

Sweat patches were removed following each 90-min training session and immediately centrifuged (Centrifuge Model 225A, Fisher Scientific Instruments, Dubque, Iowa, USA)

**Table 1.** Mean environmental conditions for each soccer training session.

| Group | Training session | $n$ | Mean ambient temperature (°C) (mean ± SD) | Mean relative humidity (%) (mean ± SD) |
|---|---|---|---|---|
| U18 | T1 | 5 | 6.1±0.9 | 79±17 |
| | T2 | 5 | 6.2±0.4 | 67±13 |
| U16 | T1 | 12 | 8.8±1.2 | 61±11 |
| | T2a | 9 | 12.4±1.6* | 59±11 |
| | T2b | 3 | 12.3±1.8* | 68±14 |
| U15 | T1 | 16 | 8.0±0.9 | 59±11 |
| | T2 | 16 | 14.6±0.9* | 58±7 |

**Note:** *, $p < 0.05$, statistically different to T1.

for sweat extraction. Analysis of each sweat sample for sodium concentration was conducted in triplicate within 24 h of collection using a conductivity analyzer (Wescor Sweat Chek 3120 Conductivity Analyzer, Logan, Utah, USA) (Boisvert and Candas 1994). Sweat patch over-saturation has been suggested to result in falsely high sweat electrolyte concentrations (Weschler 2008). Patterson et al. (2000) and Baker et al. (2009*a*) reported that local sweat patch collection can also overestimate whole-body sweat electrolyte losses (chest = 98%, 64%; back = 71%, 65%; forearm = 75%, 21%; thigh 12%, 7%). We are unable to comment on whether similar overestimations or oversaturation occurred in our group of soccer players which were measured in a cool environment, therefore the samples were not corrected.

Sodium loss in grams (g) was calculated using the following equation:

$$\text{sodium loss} = [\text{sodium concentration} \times 22.99(\text{molecular weight of sodium}) \times \text{sweat loss}]/1000$$

where sodium concentration is measured in $mol{\cdot}L^{-1}$ and sweat loss measured in litres (L).

### Statistical analyses

The data were analyzed using SPSS (version 17.0, 2010; SPSS Inc., Chicago, Ill., USA) software. Data are expressed as means ± SD. Paired $t$ tests were used to test for significant differences between T1 and T2 for each of the training-session-related dependent variables. Pearson's product moment correlation analysis was used to quantify relationships between sweat loss and selected variables (USG, body mass, age, fluid intake, sweat sodium). Statistical significance was set at $p \leq 0.05$.

## Results

### Environmental temperature and training intensity

The mean environmental conditions for each training session are summarized in Table 1. T1 sessions were generally cooler than T2 sessions with some significant differences ($p \leq 0.05$). Table 2 describes training intensity, as determined by mean heart rate, mean percentage $HR_{max}$ ($\%HR_{max}$), and mean time spent at differing levels of relative intensity. In the U15 group, heart rate and % $HR_{max}$, time spent in light, and hard and very hard intensities were significantly higher in T1 compared with T2. This difference is likely due to dif-

**Table 2.** Mean heart rate ($beats{\cdot}min^{-1}$), percent heart rate ($\%HR_{max}$) and time (min:s) spent at differing levels of intensity during all soccer training sessions by group and combined (mean ± SD).

| | | HR | | Intensity | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | $n$ | Mean HR ($beats{\cdot}min^{-1}$) | % $HR_{max}$ | Very light (<35% $HR_{max}$) (min:s) | Light (35%–54% $HR_{max}$) (min:s) | Moderate (55%–69% $HR_{max}$) (min:s) | Hard (70%–89% $HR_{max}$) (min:s) | Very hard (≥90% $HR_{max}$) (min:s) |
| U18 T1 | 5 | 141±3 | 70±2 | 12:02±5:05 | 17:34±3:17 | 24:23±5:21 | 22:41±3:35 | 9:54±4:52 |
| U18 T2 | 5 | 141±13 | 70±6 | 12:16±10:351 | 18:58±6:57 | 21:00±3:50 | 20:15±8:32 | 10:41±11:12 |
| U16 T1 | 12 | 136±7 | 66±3 | 7:36±11:51 | 27:08±4:33 | 20:01±5:20 | 17:04±5:13 | 9:03±2:44 |
| U16 T2a | 9 | 130±8 | 63±4 | 32:02±10:26* | 14:48±5:46 | 16:19±6:35 | 17:12±8:47 | 9:08±8:33 |
| U16 T2b | 3 | 126±3 | 61±2 | 34:06±5:21* | 23:20±7:26 | 18:52±10:20 | 12:52±4:07 | 3:05±2:56 |
| U15 T1 | 16 | 148±7 | 72±3 | 7:43±3:38 | 16:50±6:40 | 24:29±6:11 | 23:58±10:34 | 19:19±9:27 |
| U15 T2 | 16 | 141±6* | 68±3* | 0:11±0 | 1:09±1:26* | 19:37±7:30 | 58:42±14:38* | 7:20±4:18* |
| Combined | 66 | 140±9 | 68±3 | 16:47±12:39 | 16:31±9:37 | 20:55±6:46 | 28:55±19:18 | 11:08±8:15 |

**Note:** *, $p < 0.05$, statistically different to T1.

**Table 3.** Mean body mass change, fluid consumption (mL), and sweat loss (L) during all soccer training sessions, by group and combined (mean ± SD).

| Team | *n* | Body mass pre-training (kg) | Body mass post-training (kg) | Body mass lost (%) | Fluid intake (L) | Total sweat lost (L) |
|---|---|---|---|---|---|---|
| U18 T1 | 5 | 63.60±6.63 | 63.29±6.61 | 0.48±0.34 | 0.16±0.16 | 0.47±0.05 |
| U18 T2 | 5 | 61.53±21.30* | 61.20±21.19 | 0.54±0.14 | 0.12±0.50 | 0.45±0.16 |
| U16 T1 | 12 | 60.80±6.93 | 60.45±6.89 | 0.39±0.70 | 0.10±0.08 | 0.46±0.47 |
| U16 T2a | 9 | 58.77±7.26 | 58.55±7.33 | 0.18±0.33 | 0.22±0.19 | 0.44±0.18 |
| U16 T2b | 3 | 66.00±22.22 | 65.63±22.21 | 0.55±0.34 | 0.10±0.19 | 0.47±0.18 |
| U15 T1 | 16 | 61.56±9.11* | 60.69±9.53 | 0.95±1.46 | 0.19±0.11 | 1.06±0.75 |
| U15 T2 | 16 | 60.73±9.41* | 60.22±9.37 | 1.08±0.66 | 0.31±0.16 | 0.81±0.40 |
| Combined | 66 | 61.06±9.83 | 60.70±9.83 | 0.84±0.69 | 0.20±0.02 | 0.69±0.43 |

**Note:** *, $p \leq 0.05$, pre-body mass statistically different to post-body mass.

**Table 4.** Regional sweat–sodium concentrations (mmol·L$^{-1}$) and sodium losses (g) (mean ± SD, range) and their relationship to whole body sweat–sodium concentration.

| Regional site | No. samples | Correlation coefficients to whole body sweat* | Mean Na+ concentration (mmol·L$^{-1}$) | Sweat sodium loss (g) |
|---|---|---|---|---|
| Low back | 49 | 0.88 | 48±12 (27–68) | 0.7±0.4 (0.2–2.7) |
| Forearm | 17 | 0.88 | 51±9 (35–65) | 0.9±0.5 (0.2–2.4) |
| Scapula | 43 | 0.82 | 61±16 (32–95) | 1.1±0.6 (0.0–5.7) |
| Chest | 31 | 0.74 | 55±15 (25–82) | 0.8±0.6 (0.0–2.8) |
| Thigh | 33 | 0.88 | 60±10 (42–77) | 1.0±0.4 (0.4–2.9) |

*Data is from Patterson et al. (2000).



ferences in training sessions, as the U15 T1 training included more high-intensity shuttle running drills and a longer short-sided team game.

## Pretraining hydration status

There were no significant differences in USG between T1 and T2 measures or between team groups. The combined group mean pretraining USG was 1.018 ± 0.009 (range = 1.003–1.034). When individual data were examined 30 (45.4%) players presented to training with a USG >1.020. A total of 27 (40.9%) players arrived to training with USG between 1.020–1.029 and 3 (4.5%) players with a USG > 1.030.

## Body mass changes, sweat loss, and fluid intake

As seen in Table 3, total mean sweat loss was 0.69 ± 0.54 L with a large range of 0.04–2.8 L. There were no significant differences in body mass loss, fluid intake, and sweat loss between T1 and T2 measures or between groups ($p$ > 0.05). No player voided any urine–feces during the training sessions. Mean percent body mass loss was 0.84% ± 0.07% (range = –0.28% to 5.21%). When considering individual data, 6 (9.1%) players lost between 1% to 2% of their body mass and 8 players (12.1%) lost more than 2% of their body mass during the training. There was a wide range of fluid volumes consumed (0–600 mL). Over the 90-min training session, 42 (63.6%) athletes drank less than 250 mL and 20 (30.3%) athletes drank between 250–500 mL. Recorded beverages used during training sessions revealed that the majority of players (97%) consumed water with only 1 participant using a diluted sport drink as her fluid choice during both training sessions.

## Sweat sodium concentration

Due to a lack of sweat produced by the athletes, measurable sweat samples were not always obtained from each regional site. As seen in Table 4, of the samples taken at each site, the low back (74.2% of all samples taken at this site) and scapula (65.2% of all samples taken at this site) sites provided the greatest number of quantifiable sweat samples. Since the low back sweat patch site yielded the highest number of measurable samples and this regional site has been previously reported to have a strong correlation coefficient ($r$ = 0.88) for whole-body sweat sodium concentration (Patterson et al. 2000), the low back sweat sodium concentration was considered the best representation of the sweat sodium concentration in the participants. Mean sweat sodium concentration from this site was 48 ± 12 mmol·L$^{-1}$ (range = 27–68 mmol·L$^{-1}$). There was no significant difference in sweat sodium concentration between T1 and T2 measures for each age group or between age groups (data not shown); therefore, data were combined ($p$ > 0.05).

## Relationship between environmental-, physiological-, and hydration-related variables

There were no significant correlations found between ambient temperature and the hydration measures of fluid intake ($r$ = –0.279, $p$ = 0.72), sweat loss ($r$ = –0.281, $p$ = 0.51), percent body mass loss ($r$ = –0.251, $p$ = 0.18), USG ($r$ = 0.83, $p$ = 0.573), or sweat sodium concentration ($r$ = –0.207, $p$ = 0.311). No significant correlations were found in any intensity zone and hydration measures. In addition, there were no significant correlations between mean heart rate and %$HR_{max}$ and any hydration measures ($p$ > 0.05). Despite the minor significant differences in environmental temperatures between T1 and T2, no significant correlations

**Table 5.** Mean and range of fluid intake habits of study participants compared with published adult and youth hydration guidelines.

| Timing | Fluid intake habits of participants (mean ± SD) | 2007 ACSM Fluid Replacement Guidelines | 2006 USSA Youth Heat Stress Guidelines |
|---|---|---|---|
| Before training* | • 398.3±318.3 mL or 5.6±4.4 mL·kg$^{-1}$<br>• 2 h before<br>• Large range (0–19 mL·kg$^{-1}$) | • 5–7 mL·kg$^{-1}$ for the first 4 h<br>• ~3–5 mL·kg$^{-1}$ in the 2 h before exercise | • Child should be well hydrated having consumed 375–500 mL of fluid 30 min ahead of time |
| During training† | • Most (87.9%) did not lose>2% of their body mass<br>• Low fluid intake = 195±0.24 mL over 90 min<br>• Participants did not fully replenish losses during training<br>• 6/7 practices allowed 1 drink break only<br>• 1/7 practices had no drink breaks | • Fluid intake should be customised to prevent greater than 2% body mass | • Drinking to be enforced periodically every 20 min<br>• ~281 mL fluid/20 min for players>41 kg |
| After training* | • 418.5±315.4 mL<br>• Not enough to replace mean losses during training (688.33±427.44 mL) | • ~1.5 L of fluid is consumed for each kg body mass lost | • Fluid intake starts immediately and occurs every 20 min for 1 h |

*Fluid consumption data before and after training were taken from self-reported nutrition questionnaire.

†Fluid consumption data during training were calculated by measurement of personal fluid container mass pre- and post-training session.



were found between sweat loss and USG ($r$ = 0.011, $p$ = 0.930), body mass ($r$ = 0.012, $p$ = 0.963), age ($r$ = 0.109, $p$ = 0.930), fluid intake ($r$ = 0.279, $p$ = 0.023), or low back sodium concentration ($r$ = 0.382, $p$ = 0.072).

## Discussion

The present study is the first comprehensive assessment of the hydration status, fluid balance, and sodium losses experienced by junior elite Canadian female soccer players. The findings of this study identify a large proportion of players presented to practice in a hypohydrated state. Overall, players experienced mild dehydration and low sodium losses; however, there was a large individual variability in fluid balance and sodium loss. Several athletes experienced dehydration reflecting a loss of greater than 2% body mass, which has been associated with negative physiological and mental performance in soccer athletes (Ali et al. 2011; Edwards et al. 2007).

There was no relationship found between environmental temperature, USG, heart rate, % body mass loss and sweat rate. This concurs with similar findings by Kilding et al. (2009) and Maughan et al. (2005), who found that sweating responses could not easily be explained by hydration status, fluid intake, or training intensity. The variation in sweat response that occurred between players further emphasises the need to consider individual physiological factors when assessing an athlete's sweat mechanics.

### Pretraining hydration status

USG has been previously demonstrated as a viable tool in the assessment of hydration status of athletes (Oppliger et al. 2005), with a value of >1.020 indicating significant hypohydration and a USG >1.030 indicating severe dehydration (Casa et al. 2000). An important finding of the current study was the observation that almost half (45.4%) of the players presented to training in a hypohydrated state even though they were well aware of the objectives of the study. The mean USG level of athletes in the present study is higher than that previously reported by Kilding et al. (2009) (T1 = 1.014 ± 0.005; T2 = 1.011 ± 0.005) who assessed pretraining USG in 13 adult female elite soccer athletes before 2 training sessions in similar environmental conditions and time of day. USG values from the present study are similar or slightly lower than those found in adult male soccer athletes (Maughan et al. 2005), as well as in adolescent male hockey (Palmer and Spriet 2008) and football athletes (Stover et al. 2006).

The pretraining hydration status of study participants could have been influenced by pretraining schedules and lack of hydration education. The majority of athletes from the present study arrived to training after a full day of school and in some cases, after school sport activities. Although hydration education was not formally assessed, only (9.1%) of the athletes reported ever having worked with, or received education from, a sport nutrition professional. Pre-exercise hypohydration can be a contributing factor for decreased soccer performance, increases in core temperature, heart rate, and decreases in sweat rate (Sawka et al. 2007; Coyle 2004). Individual education and pretraining fluid recommendations are warranted.

### Fluid balance during training

There is very limited research describing the fluid balance of female adolescent soccer athletes during training. Kilding et al. (2009) found similar sweat rates (0.4–0.5 L·h$^{-1}$) and lower percent body mass losses in adult female players in a cool environment. Broad et al. (1996) reported higher sweat rates (0.8 ± 0.2 L·h$^{-1}$) during both training and competition in adult female soccer athletes in warmer environmental temperatures (30–35 °C). The participants in the present study had lower mean fluid intake during training than that reported previously (Kilding et al. 2009; Broad et al. 1996; Shirreffs et al. 2005; Maughan et al. 2005; Mao et al. 2001; Mjaanes et al. 2006). As seen in Table 5, participants did not appear to follow published recommended guidelines for hydration both during and after training (Sawka et al. 2007; US Soccer Federation 2006).

Fluid balance results were likely influenced by environmental temperatures and insufficient drink breaks given by coaches. Cool environmental temperatures may decrease sweat losses and the physiological drive to drink (Maughan et al. 2005). Of the 7 training sessions observed during this study, 6 sessions permitted only a single drink break for players. There was a high interindividual variation in fluid balance, which agrees with reports from previous studies in various sports (Kilding et al. 2009; Maughan et al. 2005; Shirreffs et al. 2005; Palmer and Spriet 2008; Sawka et al. 2007). Although mean results indicated only mild dehydration post-training, several individual athletes experienced greater than a 2% body mass loss during training. Dehydration during soccer-specific testing protocols has been found to be significantly related to elevated core temperature, heart rate, lactate production, ratings of perceived exertion, and reductions in soccer-specific skills and mental test performances (Ali et al. 2011; Edwards et al. 2007) and emphasizes the need for dehydration prevention strategies for youth athletes.

### Sweat sodium losses

This is the first study to report sweat sodium losses in adolescent female soccer athletes during training. As seen in Table 4, results of sodium losses were highly variable between athletes, with a large range of measured loss. In adult female players playing in a cool environment, Kilding et al. (2009) reported a mean sweat sodium concentration of 45.1 ± 11.4 mmol·L$^{-1}$, using the 4-site regression equation by Patterson et al. (2000), thus making comparison to the current results difficult. Because of the lack of quantifiable samples at all sites in the current participants, the 4-site regression equation used by Kilding et al. could only be applied to 6 (9.1%) athletes, and resulted in a higher mean whole-body sodium concentration of 57.7 ± 9.3 mmol·L$^{-1}$. Unpublished observations cited by Shirreffs et al. (2006) in under-21 England women soccer players during training and competition reported concentrations of 44 ± 18 mmol·L$^{-1}$, but location of regional sites tested was not indicated. Maughan et al. (2005) reported regional sodium losses (forearm, chest, thigh, and back) in adult male players in cool temperatures (5 °C, 85% relative humidity). When compared with the current study's results, the male athletes had lower sweat concentrations in back (53 ± 10 mmol·L$^{-1}$), chest (45 ± 16 mmol·L$^{-1}$), and thigh (34 ± 18 mmol·L$^{-1}$) sites, but higher values in forearm measurements (36 ± 10 mmol·L$^{-1}$).

Sweat patches were removed after the 90-min practice to avoid interfering with the training session. This could have resulted in oversaturation of the patches. Sweat patch oversaturation has been suggested to result in falsely high sweat electrolyte concentrations (Weschler 2008). The inability to reliably collect sweat samples from commonly used regional sites in adult athletes was a consistent trend in this study. This finding could prove to be an important methodological consideration for future sweat sodium testing in the female adolescent athlete population in cool environments.

The findings from this study provide valuable insight into the hydration status of the junior elite female soccer athlete; however, several limitations to this study do exist. It is important to note that fluid consumption between time of urine collection and start of training was not measured. This time varied between 15–45 min before training, and it is possible that those players who presented in a hypohydrated state in the lab before training were able to consume enough fluid to improve their hydration status prior to training. A longitudinal assessment of hydration status and fluid–electrolyte balance in different environmental temperatures as well as during match play would provide a better indicator of habits and losses. Because of the applied nature of this study, a number of variables that could have influenced fluid balance could not be strictly controlled (ie. training intensity, menstrual phase). Finally, although normal hydration and nutrition habits of players were encouraged by study investigators, there is a possibility that the usual habits of coaches and players may have been influenced by the study.

## Conclusion

This study described the pre-training hydration status as well as the fluid and sodium balance in junior elite female soccer athletes in cool environments. A large proportion of athletes presented to training in a hypohydrated state. Players experienced low mean sweat and sodium losses that were likely due to cool environmental temperatures and limited access to fluids during training. Despite this, there were large variations in individual results, with some players losing greater than 2% body mass during training and thus having an increased risk for dehydration-related performance decrements. Results of this study support previous recommendations that hydration guidelines must be personalized for athletes and that individual education is strongly indicated (Sawka et al. 2007).

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