ORIGINAL SCIENTIFIC PAPER

Collegiate soccer players consistently underestimate practice sweat losses regardless of practice sweat loss volume

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Abstract

Soccer play in hot environments can result in major fluid deficit. If competitors are unsure of their sweat losses, accurate fluid intake needs during and between training bouts cannot be established. This study evaluated sweat loss estimation accuracy among collegiate male soccer players (n = 17) following three, 90-minute practice sessions in the heat. Data were collected during the last week of pre-season training during a morning (P1; wet bulb globe temperature (WBGT) = 31.2 °C) and same day afternoon (P2; WBGT = 26.9 °C) practice. The third estimation took place after a regular season morning practice (P3; WBGT = 31.5 °C) the following week. Change in nude body mass, with adjustment for fluid intake and urine output, from pre- to post-practice was assessed to determine sweat loss volume. After each practice participants estimated their sweat loss volume by filling cups with a volume of water equivalent to the volume of sweat they believed they lost during the practice session. Sweat losses differed ($p < 0.05$) among all 3 practices (P1 2.181 ± 0.693; P2 1.706 ± 0.474; P 3.360 ± 0.956 L). Estimated sweat loss volume was less ($p < 0.001$) than actual sweat losses for P1 (0.804 ± 0.329 L; 40.2 ± 21.5%), P2 (0.672 ± 0.324 L; 40.1 ± 19.9%) and P3 (1.076 ± 0.489 L; 31.8 ± 11.6%), but there were no differences in percentage accuracy. Players estimations of sweat loss trended up and downward with actual sweat losses, but players greatly and consistently underestimated sweat losses. Visual depiction of sweat loss volume could potentially increase awareness of between training bout fluid intake needs of soccer players training in hot conditions.

Keywords: *Football, hydration, perceptual measures*

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SOCCER PLAYERS' ABILITY TO ESTIMATE SWEAT LOSSES
http://mjssm.me/?sekcija=article&artid=243

Cite this article: Davis, B.A., Bowling, L.R., Dean, T.M., Knight, S.N., Robinson, M.A., Russell, A.R., & O'Neal, E.K. (2022) Collegiate soccer players consistently underestimate practice sweat losses regardless of practice sweat loss volume. *Montenegrin Journal of Sports Science and Medicine*, 11 (2), 65–70. https://doi.org/10.26773/mjssm.220908

Introduction

It is suggested that physical activity take place in a euhydrated state to combat dehydration elicited deficits to performance (McDermott et al., 2017). However, collegiate athletes in general (Volpe, Poule, & Bland, 2009) and collegiate soccer players specifically (Clarke, Carpenter, Spain-Mansmann, Taylor, & Schubert, 2021b; Sekiguchi, Adams, Curtis, Benjamin, & Casa, 2019) often report to practice with a high prevalence of dehydration based

Received: 7 June 2022 | Accepted after revision: 20 August 2022 | Early access publication date: 30 August 2022 | Final publication date: 1 September 2022

Conflict of interest: None declared.

on urinary hydration markers. Soccer match play rules also limit opportunities for fluid consumption. Restricted fluid intake is commonly reported to result in increased core temperature, cardiovascular strain, and higher perceived exertion (Ali, Gardiner, Foskett, & Gant, 2011; Edwards et al., 2007; McGregor, Nicholas, Lakomy, & Williams, 1999) during soccer research. However, the effects of dehydration on soccer performance are equivocal.

Investigators reported fluid restriction had no influence on a variety of soccer skill-based tasks or shuttle running challenges in cool training conditions among male soccer players (Owen 2013). Female soccer players also presented no difference in performance during six sets of Loughborough Shuttle Tests when fluid intake was allowed or disallowed (Ali et al., 2011). In contrast, McGregor et al. (1999) found male shuttle running performance in the same protocol design as Ali and colleagues (2011) during fluid restriction trials began trending towards impaired running performance on the fourth and fifth 15 min shuttle running bouts and reached statistical significance during the 6th shuttle bout. Additionally, sweat losses incurred through 45 min of cycling followed by 45 min of match play reduced distance covered during a shuttle running task when no fluids were ingested (Edwards et al., 2007).

Creating individualized fluid intake schedules for athletes during or between training or competition bouts is not possible without an approximate knowledge of induced sweat loss volume. A recent review of 9 studies that included 243 athletes that were asked to estimate their sweat losses after training reported overwhelming support that sweat losses are vastly underestimated regardless of sex or sport type in moderate to hot environments (O'Neal et al., 2020). Three groups of team sport (rugby and basketball) athletes were observed in these studies (Love, Baker, Healey, & Black, 2018; Muth, Pitchett, Pritchett, DePaepe, & Blank, 2019; Thigpen, Green, & O'Neal, 2014), but we are unaware of any sweat loss estimation investigations with soccer players. Furthermore, to our knowledge, only three studies have examined sweat loss estimation during more than one activity session to determine the strength of conviction of athletes estimating sweat losses (Davis, O'Neal, Johnson, & Farley, 2019; Shaver, O'Neal, Hall, & Nepocatych, 2018; Thigpen et al., 2014). Therefore, the purpose of this study was to evaluate sweat loss estimation accuracy among collegiate, male soccer players following three, 90-minute practice sessions with different coaching focuses during hot climate training sessions. The authors hypothesized that athletes would consistently and greatly underestimate their sweat losses across the practice sessions.

Methods

Participants

Male, National Collegiate Athletic Association (NCAA) Division II soccer players practicing in the hot and humid southeastern region of the United States (latitude = north 32° 22' 0.498") were recruited for this study. Seventeen players (age = 21 ± 3 y; height = 178 ± 123 cm; body mass = 68.7 ± 15.8 kg) provided sweat loss estimates across three practices. All participants passed a physician administered physical and standard health questionnaires for physical activity participation. Written informed consent was obtained by participants prior to participation. This study was approved by the Auburn University at Montgomery Institutional Review Board and was conducted in accordance with the Declaration of Helsinki.

Procedures

Data collection took place during three coach led practices. The first two practices included a mid-morning (P1) and afternoon practice (P2) on the same day during the final week of pre-season training camp. The third practice (P3) took place the following week (i.e. first week of in-season) during the players' normal in-season mid-morning training time. Each practice lasted 90 minutes but consisted of different training emphases. A detailed description of the practices and environmental conditions is provided in Table 1. A schematic of data collection procedures for practice is provided in Figure 1.

Table 1. Description of practice conditions and activities.

	P1	P2	P3
Time of day	10:00 AM	5:00 PM	10:00 AM
Duration (min)	90	90	90
WBGT (^{0}C)	31.2	26.9	31.5

Practice activities (duration in min)

P1	P2	P3
- Dynamic warm up (15) - Speed and agility training (15) - Soccer skills training (30) - Scrimmage (30)	- Dynamic warm up (15) - Soccer skills training (15) - Scrimmage (60)	- Dynamic warm up (15) - Soccer skills training (15) - Scrimmage (60)

During each practice, the following procedures took place in regards to sweat loss assessment and estimation. Sweat loss volume was determined by change in nude body mass from pre- to post-practice with consideration for fluid intake (no participants urinated or defecated between body mass assessments). It was assumed each kilogram of body mass change was equal to 1 liter of sweat loss volume. No corrections were made for differences of mass lost in sweat loss solutes, respiratory tract water evaporation, or metabolic related shifts in total body water. A private room with the scale platform (BWB-800, Tanita Corporation, Tokyo, Japan) located inside and digital output screen outside for an investigator to record results was used to assess body mass to the nearest 0.1 kg without unblinding players to their change in body mass.

Following measurement of pre-practice nude body mass, participants were restricted from consuming any fluids until the start of practice. Immediately prior to practice, investigators provided each participant with a chilled, manufacturer-sealed bottle of water containing 1,000 ml of water. Participants were instructed to consume the water ad libitum during the upcoming practice session and directed to avoid rinsing their mouth, spitting the water out, or spraying the water on their face or body. Participants were instructed to inform investigators if they needed a new bottle during practice. Bottles were weighed before and after practice

 DOI 10.26773/mjssm.220908

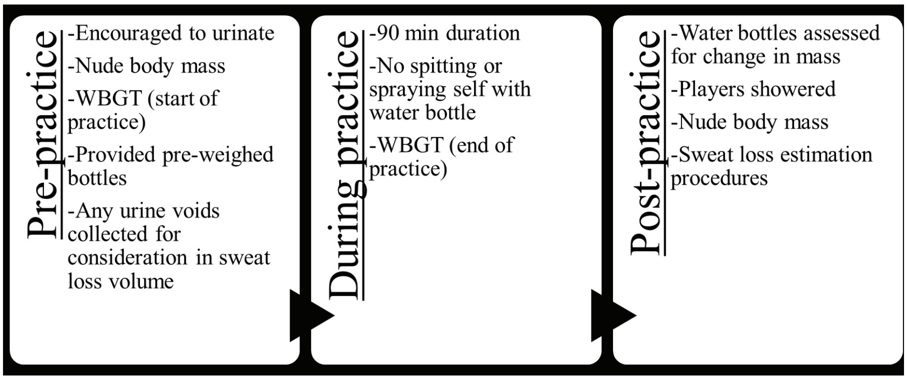

Figure 1. Schematic of data collection procedures for all practices.

using a precision scale (KD-200, Tanita Corporation, Tokyo, Japan) to determine fluid intake volume. No other beverages were provided to participants during practice sessions. Wet-bulb-globe temperature (WBGT) was monitored (HT30: Heat Stress WBGT Meter, Extech Instruments, Waltham, MA) immediately before and after the practice session and the average was recorded.

Players showered and cleaned up from practice then had nude body mass assessed in the same fashion as pre-practice. Next, players completed the sweat loss estimation procedures. This process involved the players individually being presented with a large stack of empty papers cups that each would hold ~250 mL of water. Two, 3.75-liter jugs were also on the table. Players were asked to use the water in the jugs to fill the paper cups with the volume of water equal to their sweat losses incurred during practice. The cups were then assessed for mass in front of the players and the total mass of the fluid was described to the players in terms of volume to the nearest milliliter. Participants were allowed to adjust the volume of water in the cups at this point if desired. Participants were instructed to not discuss their estimations with teammates.

Statistical Analyses

All data analyses were performed using IBM©, SPSS© Statistics version 26. Data are reported as mean ± SD. One-way repeated measures ANOVA was used to compare differences in sweat loss, fluid intake, and sweat loss estimations across practice sessions. Mauchly's test was used to determine sphericity. Greenhouse-Geisser adjustments were made if applicable when determining significance of main effects. Bonferroni corrections were used for all post hoc comparisons. Estimated sweat loss volumes and actual sweat losses for each practice were compared using paired t tests. An a priori alpha level ≤ 0.05 was considered to represent statistical significance.

Results

Sweat loss and sweat loss as percent body mass both exhibited main effects for practice sessions ($p < 0.01$) with all practices differing from each other (Table 2). Practice fluid intake was lower during the afternoon practice, but neither morning practices differed from each other (Table 2). Sweat loss accuracy did not differ among practices (Table 2). Estimated sweat losses were less than actual sweat losses for all three practices (Figure 2).

Table 2. Fluid intake and sweat loss outcomes (n = 17; mean ± SD).

	P1	P2	P3
Fluid intake			
during practice (L)	1.823 ± 0.757^{B}	$0.922 \pm 0.569^{A,C}$	2.190 ± 0.524^{B}
Sweat loss			
loss (kg)	$2.181 \pm 0.693^{B,C}$	$1.710 \pm 0.474^{A,C}$	$3.361 \pm 0.956^{A,B}$
% body mass	$2.98 \pm 0.88^{B,C}$	$2.31 \pm 0.59^{A,C}$	$4.51 \pm 1.06^{A,B}$
estimated (kg)	0.804 ± 0.329^{C}	$0.672 \pm 0.324^{A,C}$	1.076 ± 0.489^{B}
accuracy (%)	40.2 ± 21.5	40.1 ± 19.9	31.8 ± 11.6

^{A} = different from P1; ^{B} = different from P2; ^{C} = different from P3 ($p < 0.05$).

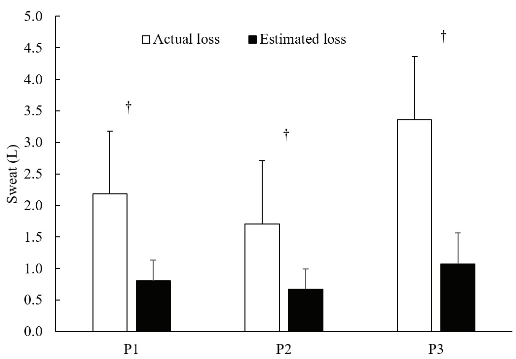

Figure 2. Comparison of absolute sweat losses to sweat loss estimates (n = 17; mean ± SD). † = ($p < 0.01$). P = practice session..

Discussion

This study was the first investigation to our knowledge that examined soccer athletes' abilities to estimate their sweat losses during hot training conditions at any level of competition. Furthermore, estimation consistency was also able to be compared during practices of the same duration but with different volumes of sweat loss due to differences in environments or training intensity. The main findings confirmed our hypotheses that players would consistently and greatly underestimate their sweat losses across practices regardless of sweat volume produced based on environmental and practice activities (Table 2 and Figure 2). It is well established that soccer training and competition in the heat can produce significant sweat losses. Professional and international level soccer competitions often take place in thermoregulatory challenging conditions. For example, the 2022 World Cup will be played in Qatar where regional soccer match environments can average temperatures of 45 °C and produce match sweat losses exceeding 3 L (Al-Jaser & Hasan, 2006). Castro-Sepulveda, Astudillo, Letelier, and Zbinden-Foncea (2016) reported over 50% of internationally competitive female soccer players arrived for practice or formal matches presented USG values exceeding 1.030 when living and training in hot climates. While training in cooler environments reduces odds of rampant team dehydration based on urinary hydration indicators (Gibson, Stuart-Hill, Pethick, & Gaul, 2012; Klimesova et al., 2022), formal collegiate soccer training and competition in the United States begin in late summer. These increased temperatures create a significant hydration challenge for many athletes. It is possible that athletes might adjust their fluid intake more adequately if they are aware of their actual sweat loss volume from training.

In this study, the mean sweat loss during the most intense and thermoregulatory challenging practice (P3) exceeded 3 L and 4% of body mass (Table 2). During P2, a cold front and thunderstorm altered environmental conditions which cut sweat losses in half even though practices were of the same duration and separated by only one week (Table 2). The positive takeaway from the sweat loss estimation of the athletes across practices is that estimated volume in absolute terms trended to match the increase or decrease of sweat loss volume (Table 2), and that the relative estimations (i.e. percentage of underestimation; Figure 2) did not change across practices. In summary, players were aware of when they were sweating more or less in relative terms. However, these sensitive adjustments in sweat loss estimation were essentially meaningless due to the vast underestimations of absolute sweat loss volume (Table 2; Figure 2).

While no comparisons can be made to female soccer players or soccer players at other competition levels, past evidence suggests extrapolation to these other populations is reasonable. Male and female, NCAA Division II basketball players underestimated their in-season practice sweat loss by ~30% and 65%, respectively (Thigpen et al., 2014). Both men's and women's NCAA Rugby Union players were found to also underestimate their practice sweat losses by 47 and 79% (Muth et al., 2019). In the only other team sport sweat loss estimation study we are aware of, Love et al. (2018) found professional rugby players exhibited some of the greatest and consistent sweat loss underestimations ever reported at 73 ± 17%. Despite greater chance of exposure to hydration education, these 38 professional, male rugby players were much less accurate estimators of their sweat losses than almost all cohorts of amateur athletes across a variety of training types (O'Neal et al., 2020).

In regards to consistency of estimations, only two studies are available in which duration and physical activity demands are similar between trials. Shaver et al. (2018) found female runners consistently underestimated sweat losses by half or more when completing two outdoor 15-km runs in similar, temperate environmental conditions. Davis and colleagues (2019) altered well-trained, male runners' sweat losses by controlling room temperature during 1-h treadmill runs of the same pace. In agreement with the current investigation, the runners estimated greater absolute sweat losses during the warmer condition, and mean estimation accuracy by percentage did not differ (62 vs 65% of actual sweat loss). Based on our extensive research history on sweat loss estimation accuracy, we do not believe that sweat loss volume is not on the forefront of athletes' minds. However, the consistency across studies suggests that when asked, athletes have a somewhat fixed, albeit incorrect, estimation volume developed.

A recent meta-analysis (Chapelle et al., 2020) concerning soccer hydration profile confirms that most research has focused on professional (Aragón-Vargas, Moncada-Jiménez, Hernández-Elizondo, Barrenechea, & Monge-Alvarado, 2009; Duffield, McCall, Coutts, & Peiffer, 2012; Kiitam et al., 2018; Voitkevica, Pontaga, Timpmann, & Ööpik, 2014) and youth (Arnaoutis et al., 2013; Phillips, Sykes, & Gibson, 2014; Silva et al., 2011; Williams & Blackwell, 2012) level soccer competitors. There is a lack of investigations examining hydration profiles for NCAA soccer players, but hydration research is expanding for both men's (Sekiguchi et al., 2019) and women's (Clarke, Carpenter, Spain-Mansmann, Taylor, & Schubert, 2021a; Mattausch, Domnik, Koehler, Schaenzer, & Braun, 2017; Wainwright et al., 2020; Wang et al., 2020) teams. Collegiate soccer players have continual contact with athletic trainers, and a growing number of universities are now employing registered sport dieticians, creating an excellent environment for hydration education interventions. A recent intervention with players preparing for United European Football Association matches found the rate of players reporting with high USG could be drastically reduced by educational seminars and alerting players to their actual pre-activity USG values (Mohr, Nólsøe, Krustrup, Fatouros, & Jamurtas, 2021). Intentional and focused hydration intervention based on pre-activity USG has also been found to be efficacious on a small scale for collegiate women soccer players (Mattausch et al., 2017). The current authors propose that if widespread dehydration is repeatedly detected for collegiate soccer players using urine color or specific gravity, athletic training and nutrition staff should consider taking steps to develop a sweat loss profile that can be shared with athletes.

This is a fairly simple process that would likely not require significant financial or human resources. An assessment of nude body mass measured before and after practice would provide pertinent information in creating individual sweat loss profiles for athletes. This process can be completed quickly by appropriate personnel (i.e. sport nutrition staff, not coaches) with a digital scale placed in a privacy room and scale reader located outside the room. Collegiate athletes almost universally drink from their own water bottles during practice, which can easily be weighed pre- and post-practice to offset fluid intake when calculating change in body mass to determine sweat losses. Players should be informed to not spit

 DOI 10.26773/mjssm.220908

out or spray their bottled fluids on themselves during practice. Additionally, players should also be encouraged to complete a void prior to initial weigh-in so urinary or fecal losses do not result in calculation errors. To further simplify the process, data collection could take place with smaller groups during a practice versus trying to test all team members at once.

It is important to also consider practice conditions as environment and duration will impact sweat loss. Sweat loss estimate procedures conducted during moderate and high thermoregulatory challenging conditions based on the team's local climate could help provide fluid intake recommendations more accurately reflecting real time practice sweat losses without repeatedly completing sweat loss determination protocols. Individual player sweat loss rate profiles for time could also be easily calculated for practices of different duration. The same procedures could also be undertaken during exhibition matches early in the season with considerations based on playing time.

In summary, soccer players consistently and vastly underestimate their sweat losses across a variety of practice conditions. Soccer players training in the heat are highly susceptible to begin training in a state of dehydration. Individual hydration plans for both during and between practices can be developed by sports medicine staff without significant cost or time by devolping a sweat loss profile for players. Visually displaying sweat loss volume for each player by depicting their volume of sweat loss in terms of their practice beverage bottles might reinforce the volume of fluid athletes should attempt to consume during and between training or competition bouts. Environmental factors are the major limitation of the current study. Soccer players may have different prediction accuracy levels when training in cool or cold environments or environments with very low humidity levels, unlike those experienced in the current study. Although the literature does not support differences in estimation accuracy based on competition level of team sport athletes or on basis of sex, professional or female soccer players may not underestimate sweat losses in a similar pattern as male, collegiate soccer players. Future investigations are warranted to determine if other soccer populations experience similar underestimation values as displayed in this study and if estimations differ based on environmental conditions. Whether sweat loss estimates influence fluid intake of soccer players or if sweat loss estimation accuracy hydration education can improve individual and team hydration levels is also worth being explored.

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