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Hydration Status and Perception of Fluid Loss in Male and Female University Rugby Union Players

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ABSTRACT

International Journal of Exercise Science 12(3): 859-870, 2019. Rugby union players are at risk for dehydration due to the high physiologic demand of the sport (~7.5 MJ/game). Dehydration could be due to lack of knowledge of fluid lost during activity. Therefore, the purpose of this study was to observe the hydration status and sweat loss estimations of male and female university rugby union players over three consecutive training sessions. Body mass, urine specific gravity (USG), and self-reported thirst scores were recorded pre and post training sessions. Sweat loss estimations were recorded post training session. After estimations, participants were shown his or her actual sweat loss in hopes of improving estimations over the three sessions. Paired *t*-tests were used to determine significance between pre and post training USG, thirst level and body mass for each day. A general linear mixed-effect model was used to determine significance of the difference between variables within gender and within days. Mean body mass changes did not exceed 2% lost for either gender on any of the three training sessions. Males significantly underestimated sweat loss by ~81% ($p<0.01$) after session one and improved estimations to ~36% after session three, however still significantly underestimated ($p<0.01$). Females also significantly underestimated sweat loss by ~64% on day one ($p<0.01$), and also improved estimations to ~60% on day three, however, still significantly underestimated ($p<0.01$). Results indicate that, on average, the participants remained in a euhydrated state throughout the training sessions. Findings also show that through education participants can improve perceptions of sweat loss to remain in euhydrated state.

KEY WORDS: Fluid balance, urine specific gravity, body mass, thirst

INTRODUCTION

For decades, the relationship between hydration status and performance has been closely evaluated, with hydration status has been linked with both physical and mental performance (8, 13). Hydration is regulated by homeostatic mechanisms that control fluid loss and retention through osmorecptors in the hypothalamus, with the posterior pituitary releasing antidiuretic hormone thereby balancing renal reabsorption / excretion. Vigorous exercise increases core temperature, which increases blood flow to the skin to help dissipate heat through sweat, thus, decreasing blood flow to the exercising muscles and impairing exercise capacity (4). Core temperature increases at a rate of 0.15°C to 0.20°C for every 1% body weight lost (16). Clothing worn, metabolic rate, and environmental conditions can all influence sweat rate (25). If sweat lost is not adequately replaced, the increase in core temperature can cause headache, nausea, general malaise, and ultimately hyperthermia (14). The physiologic strain is augmented if the individual begins activity in a dehydrated state (26).

Dehydration is the process of losing body water. The National Athletic Trainers' Association (NATA) recommends using a combination of methods to assess hydration status, including body mass change, urine color or urine specific gravity (USG) after first morning void, and thirst level to track hydration status (16). Hypohydration is a significant deficit of body fluid caused by dehydration. Hypohydration from an athletic perspective is classified as mild (2-5% body mass deficit) or severe (>5% body mass deficit). Hyperhydration is an excess of body water content, being >1% body mass gained. Euhydration is a state of optimal total body water content, ranging from 1% hyperhydration to 2% hypohydration. It is recommended that hydration strategies keep the body in an euhydrated state for optimal fluid balance (16). According to the American College of Sports Medicine (ACSM), a fluid loss of 2% body mass decreases cardiovascular and cognitive performance in warm/hot conditions, and a fluid loss of 3% body mass can degrade the same performance factors under cold stress (25). Urine specific gravity (USG) after first morning urine void has been shown to be a valid scale of hydration status in athletes (19). USG is a urinalysis assessment that compares the concentration of a urine sample with that of distilled water (16). This is used to assess kidney function as well as an individual's hydration level. USG is most commonly assessed using a refractometer (19). A USG of < 1.025 indicates a euhydrated state, a hypohydrated state ranges from 1.026 to 1.029, and any value 1.030 or greater indicates a severe hypohydrated state (31).

Despite the importance of maintaining a euhydrated state, studies have shown individuals are not adequately replacing fluid during exercise (20, 23). The ACSM recommends replacing a greater volume (125%-150%) of fluid lost to achieve effective rehydration (31). It is hypothesized that inability to adequately replace fluid during exercise is due to lack of awareness of how much fluid is lost. O'Neal et al. (18) examined the hydration status and perception of fluid lost in 39 runners (19 male, 20 female) during a one hour outdoor run in high ambient temperatures (24.1 ± 1.5 °C) at a self selected pace. It was found that males had an average of 2.3% body mass deficit from pre to post run, with females losing an average of 1.9%. Results also suggested that runners significantly ($p<0.01$) underestimate fluid loss by ~50% and replaced only ~67% of fluid lost. No statistically significant differences in estimation accuracy were found between men and women, however there was a significant difference between total sweat losses, with men losing more fluid (18). Thigpen et al. (30) studied the hydration status and perception of fluid lost of 22 university basketball players (11 males, 11 females) over two practices. Results suggested that both genders, especially females, underestimated sweat loss by over 50%, although the majority of the players did not accumulate more than 2% total body mass lost during practice (30).

Rugby union is an intermittent team sport with high physiologic demand. A rugby union game is played between two teams consisting of 15 players, over two 40-minute periods. Various demands are placed on the body during a rugby union match or training session, including jogging, sprinting, jumping, tackling, rucking and scrummaging (6). During a match, on average players cover 5158 ± 200 m (front row) to 7098 ± 778 m (scrum-halves) (2). The majority of this work is performed at 80-85% VO_2max, with an estimated energy expenditure of 7.5 MJ (5). With the amount of work performed at a high level in rugby union, fluid balance is of great concern during practice and match play. Cohen et al. (4) suggested that mean rectal temperature in elite male rugby players increased by 2°C with an average of 2.5% body mass lost during match play in a mean ambient temperature of 24°C. With a fluid loss of greater than 2%, it is evidence that rugby players are not accurately aware of amount of sweat lost during play.

Although there is research examining hydration status in elite rugby players, there is little research on hydration status of university rugby players (4,10,17). Moreover, there is a lack of data comparing hydration status of male and females in comparable conditions (30). The National Athletic Trainers' Association (NATA) identifies using a combination of body mass changes, USG, and thirst level as the best way of monitoring hydration status in athletes (16). Despite this, there is a lack of information examining hydration status using these three measures in the same participant pool. To our knowledge, there are no studies examining hydration status and perception of hydration over three consecutive training sessions.

Therefore, the purpose of this study was to observe the hydration status using body mass changes, USG changes and a self-reported thirst scale, in male and female university rugby union players over three consecutive training sessions. Additionally, this study aimed to examine changes in sweat loss estimations and to determine if estimations of sweat loss changed over the three training sessions.

METHODS

Participants

Thirty-six healthy rugby union players, males (n=20 males; n=16 females) were recruited from the Central Washington University (CWU) Rugby teams for this observational, field-based study. Participants had to be a member of either the CWU Men's or Women's Rugby team and eligible to fully participate in all training sessions, including practice and weight lifting. The University's Athletic Medicine Staff determined ability to participate in the training sessions. Average age, body mass and height were calculated for males (19.6 ± 1.4 yr, 96.1 ± 12.3 kg, 182.4 ± 6.2 cm) and females (20.6 ± 1.9 yr, 77.8 ± 15.0 kg, 158.1 ± 39.7 cm). All participants were given a written explanation of the study procedures and required to provide a written informed consent before beginning data collection. The Central Washington University Human Subjects Review Committee approved all procedures. Those that were unable to participate in one of the practice or weight-lifting sessions, either due to injury or personal reasons, were excluded from the participation.

Protocol

This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (21). Investigators collected data from mid-to-late March in the midst of rugby union training. Measurements were taken over three rugby training sessions. Males and females were assessed over three training sessions spanning a four-day period, with a day off in-between the second and third training sessions. For the males, the first training session consisted of outdoor rugby practice. The second and third training sessions consisted of weight lifting indoors, immediately followed by outdoor rugby practice. The weight lifting sessions were completed at a moderate intensity and consisted of a variety of lifts, including but not limited to, bench press, hang clean, front squat, and core exercises. For females, each training session consisted of only outdoor rugby practice. Weight lifting was included in the second and third training sessions for males as per the schedule organized by the coaches and was included to keep the study strictly observational. For both genders, the first practice came following a day of no rugby practice or weight lifting. Rugby practices were conducted by the CWU rugby coaching staff and weight lifting was conducted by the CWU strength and conditioning coach. Before arrival to the training sessions, participants were instructed to bring an extra set of dry garments for pre and post training body mass measurements.

Upon arrival to the first training session, participants were asked to rate their level of thirst, on a scale of 0 to 10, with 0 being not thirsty at all and 10 being very thirsty. Participants were then asked to void their bladder, and a urine sample was collected. Immediately after voiding their bladder, participants were weighed on a weigh beam scale (Detecto, Webb City, MO, USA). Participants were then given their own personal, 32-ounce (946 ml) water bottle. Once all pre-training measurements were obtained, participants were instructed to continue their normal drinking routine. Participants had free access to their personal water bottles throughout the entire training session. As water bottles became empty, the amount of water consumed was recorded and the investigators refilled water bottles. Fluid consumption during this period was limited to water only.

After the training session, participants dried off any sweat accumulated during training and changed back into the same dry clothes worn during pre-training body mass measurements. Participants were then asked to void any urine accumulated during practice. Body mass was again measured to evaluate sweat loss. Participants were then asked to rate their thirst level on a scale of 0 to 10.

To examine perceived sweat loss, participants were given a stack of 532 ml cups and a pitcher containing approximately five liters of water. Participants were asked to pour the amount of sweat they believed to have lost into the cups (mass=volume). Once these estimations were made, participants were then shown how much sweat they actually lost, using the same 532 ml cups.

Temperature and relative humidity in the weight room and on the rugby pitch were measured using a digital thermometer (Perception II, Davis, Hayward, CA). Environmental measurements were taken at the beginning and the end of both the weight lifting and rugby practice. Temperatures, humidity, and duration of training sessions are listed in Table 1. USG was measured using a digital refractometer (SUR-NE 300, Atago, Tokyo, Japan). To produce a reading, the tip of the refractometer was inserted one inch into the urine sample and the examiner pressed the 'start' button until a value was shown. Each urine sample was measured three times within 30 minutes of collection. Urine samples were disposed of immediately after measurements are recorded.

Table 1. Environmental conditions for each training session. (Mean ± SD)

Training Session (Day #)	Temperature (°C)	Humidity (%)	Duration (min)
Men's Practice (1)	8.5 ± 2.1	46.5 ± 9.2	90
Men's Weight-Lifting (2)	21.5 ± .7	16 ± 1.4	50
Men's Practice (2)	8.5 ± 2.1	47.5 ± 7.8	133
Men's Weight-Lifting (3)	21 ± 1.4	35.5 ± .7	50
Men's Practice (3)	7 ± 0	88 ± 1.4	106
Women's Practice (1)	11 ± 1.4	57.5 ± 3.5	95
Women's Practice (2)	11.5 ± .7	39.5 ± 3.5	81
Women's Practice (3)	11.5 ± 2.1	48 ± 2.8	90

Statistical Analysis

Results are presented in means ± SD. Paired *t*-tests were used to determine significance between pre and post training USG, thirst level and body mass for each day. A generalized linear mixed-effect model was used to determine significance of the difference between perceived sweat loss versus measured sweat rate, rate of fluid consumption, body mass lost, pre training USG, post training USG, pre-training thirst scale, and post training thirst scale, within gender and within days. Statistical significance was accepted at $p < .05$. Data analyses were conducted using SPSS (version 21.0 SPSS Inc, Chicago, IL).

RESULTS

Body Mass: Changes in body mass for both genders are displayed in Table 2. Males decreased body mass across all three days, however, females gained body mass on days one and two and lost mass on day three. Mean body mass changes never exceeded 2% lost or 1% gained for either gender on any of the three days. Males lost significantly more body mass than females on day one (0.8 ± 0.6 kg) ($p<0.01$) and day two (1.4 ± 0.6 kg) ($p<0.01$), with no significant difference in body mass changes between genders on day three (0.4 ± 0.6 kg) ($p>0.05$).

Table 2. Body mass changes by gender. (Mean ± SD)

Gender (N)	Day	Mass Change, kg	Mass Change, %
Male (20)	1	-0.5 ± 0.5*	-0.6 ± 0.6
	2	-1.1 ± 0.6*	-1.1 ± 0.5
	3	-0.5 ± 0.6*	-0.5 ± 0.7
	Total	-0.7 ± 0.6	-0.7 ± 0.6
Female (16)	1	0.3 ± 0.6	0.3 ± 0.8
	2	0.3 ± 0.5*	0.3 ± 0.6
	3	-0.1 ± 0.7	-0.2 ± 1
	Total	0.2 ± .6	0.1 ± 0.8

Note: * significantly different from pre to post training, $p < 0.05$

USG: Pre and post training USG data for both genders are displayed in Figure 1. On average, males and females arrived to training and finished training in a euhydrated state on all three days. Females completed training on day three were significantly more dehydrated compared to their pre training status on day three (1.023 ± .007), which was also significantly more dehydrated than males post training on day three (1.017 ± .008) ($p=0.03$). Females also became significantly more dehydrated from pre-training on day three (1.010 ± .008) ($p<0.01$). Ninety-seven percent of males arrived to training in a euhydrated state over the three days as compared to eighty-eight percent of females. Three percent of males and fifteen percent of females left training in a hypohydrated state.

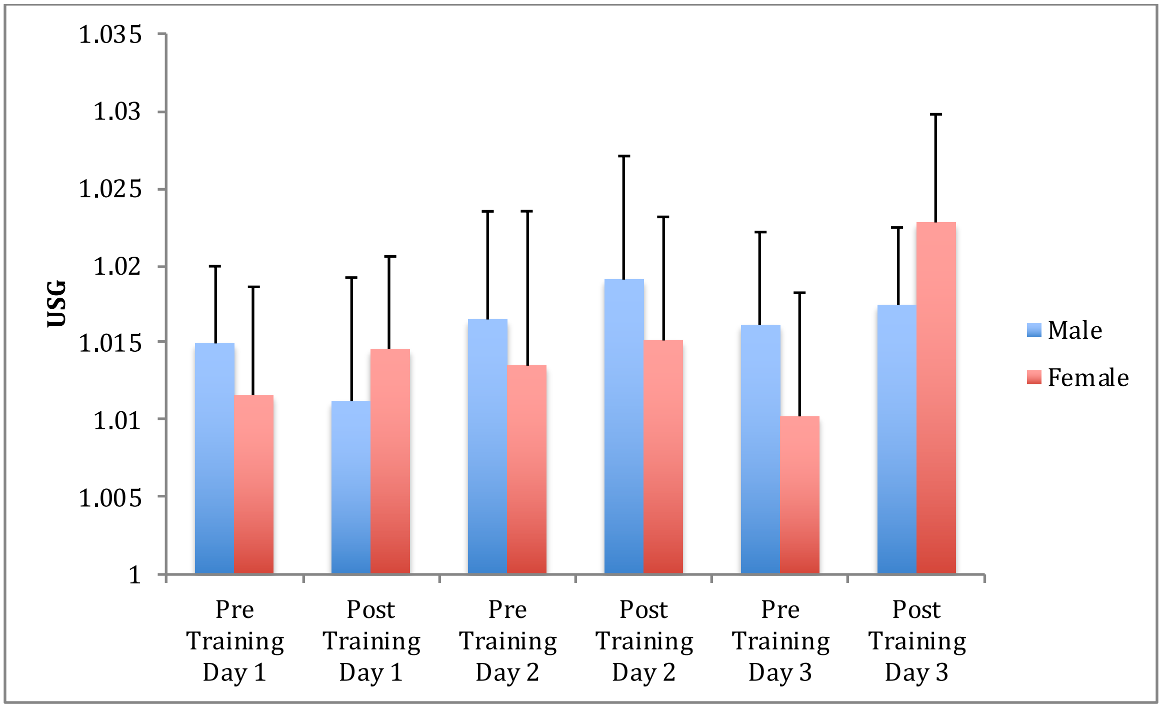

Figure 1. Mean pre and post training Urine Specific Gravity (USG) readings by gender.

Fluid Intake and Sweat Rate: Hydration data is displayed in Table 3. Among the female participants, there was a thirty-five percent increase in sweat rate and a six percent increase in fluid intake from day one to day three. Males sweat rate decreased by thirty-six percent and fluid intake decreased by thirty-one percent from day one to day three. Males sweat rate (13.3 ± 3.6 ml/kg/hr) was significantly higher than females (7.5 ± 3.5 ml/kg/hr) on day one ($p<0.01$). Conversely, males (8.5 ± 3.0 ml/kg/hr) had a significantly lower sweat rate than females (11.5 ± 7.7 ml/kg/hr) on day three ($p=0.04$).

Table 3. Hydration status and fluid loss estimations by gender.

Gender (N)	Day	Fluid Intake		Sweat Lost			
		Total, ml	Rate, ml/kg/hr	Total, ml	Rate, ml/kg/hr	Estimation, ml	Underestimation, %
Male (20)	1	1361.9 ± 482.5	9.4 ± 3.3	1917.8 ± 517	13.3 ± 3.6	372.6 ± 184.2*	80.6 ± 12.6
	2	1876.4 ± 637.9	6.4 ± 2.1	3023.9 ± 889.4	10.3 ± 2.8	857.6 ± 374.3*	71.6 ± 13.4
	3	1628 ± 336.7	6.5 ± 1.2	2136.7 ± 846.1	8.5 ± 3.0	1324.9 ± 630*	38 ± 30.2
Female (16)	1	1194 ± 483.8	9.7 ± 3.6	927.9 ± 445.4	7.5 ± 3.5	334.6 ± 243.8*	63.9 ± 71.1
	2	1085 ± 569	10.3 ± 6.2	804 ± 423	7.7 ± 4.6	460 ± 282.6*	42.8 ± 36.5
	3	1201.4 ± 643.6	10.3 ± 5	1334.5 ± 944.4	11.5 ± 7.7	528.6 ± 285.3*	60.4 ± 212.4

Note * significantly different than total measured sweat loss, p<0.05.

Thirst Perception: Self reported thirst level is displayed in Figure 2. Mean thirst level decreased from pre to post training on all three days for both genders. There was a ~27% decrease in thirst level from pre to post training in males and a ~17% decrease in thirst level from pre to post training in females. There were no statistically significant (p>0.05) differences in post training thirst levels between days within gender.

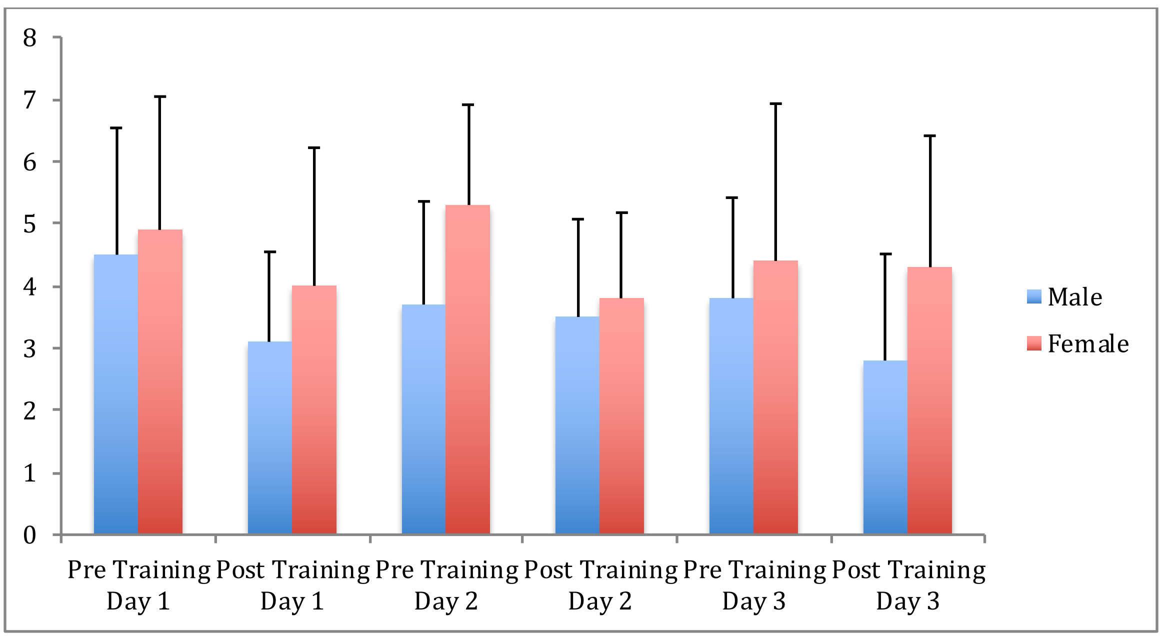

Figure 2. Pre and Post training mean thirst levels by gender. (Mean ± SD)

Perception of Fluid Loss: The differences between sweat loss estimations and measured sweat loss were substantial. Sweat loss estimations and significance are displayed in Table 3. Both genders underestimated sweat loss on all three days. Males underestimated sweat loss by ~81%, ~72%, and~38% respectively. Females also underestimated sweat loss by ~64%, ~43%, and ~60% respectively. Male's underestimations were much greater as compared to females on day one

($p<0.01$) and day two ($p<0.01$), with no significant difference ($p>0.05$) in underestimations between genders on day three.

DISCUSSION

The purpose of this study was to observe the hydration status, using body mass changes, USG changes and a self-reported thirst scale, in male and female university rugby union players over three consecutive training sessions. Additionally, this study aimed to examine changes in sweat loss estimations and to determine if estimations of sweat loss changed over three consecutive days. The primary findings were that (a) all participants body mass changes did not exceed 2% lost or 1% gained during the three training sessions, (b) 97% of males and 88% of females came into training sessions in a euhydrated state and were able to maintain this state throughout practice, per USG readings (c) mean sweat rate and mean fluid consumption decreased over the three days in males, and increased over the three days in females, (d) mean self-reported thirst decreased from before training to after training in both males and females, (e) both males and females underestimated sweat loss on all three days. However, both genders improved mean sweat loss estimations as compared to measured sweat loss across the three training sessions.

In order to appropriately track hydration status, the NATA recommends using a combination of body mass changes, urine color or USG and thirst sensation (16). When these three variables are assessed, individuals can be properly educated and given recommendations regarding personal hydration status.

In order to avoid performance decrements athletes should not lose more than 2% or gain more than 1% body mass to maintain a euhydrated state and optimize performance (16, 25). With the exception of one male participant on day one and day two, both male and female participants stayed below 2% body mass lost throughout all three training sessions, remaining in a euhydrated state. These findings support results shown by Meir et al. (17) who examined body mass changes in male rugby union players during a four-game, ten-day tournament. Over four games mean body mass changes were 0.9 ± 0.9 kg (1 ± 0.9%); players maintained a euhydrated state over multiple days of match play (17). The findings of Cohen et al. (4) stating that rugby players lost mean 2.5% body mass during match play could be due to higher ambient temperatures (24°C, 32%) as compared to ambient temperatures in the current study (Table 1). Ambient temperatures of the current study were ~60% lower than that of the Cohen et al. (4) study. With greater ambient temperatures, the body has a greater need to dissipate body heat. It is possible that participants in the current study would have had substantially greater fluid loss, and more need for fluid replacement, if higher ambient temperatures were available for the study. Furthermore, higher ambient temperatures could have also led to greater fluid loss estimations.

It should also be noted that the menstrual cycle can affect water retention in females. For example, the luteal phase can increase body water and body mass by up to two kilograms. Phases of the menstrual cycle were not tracked in the females of the current study. Due to the great effect of water retention during the luteal phase, future studies should monitor body mass changes and hydration status while tracking phases of the menstrual cycles in females.

Voluntary dehydration is the phenomenon in which individuals who exercise replace fluids at a slower rate in which they lose it (24). Although remaining in a euhydrated state as a group, males' inability to maintain pre-training body mass throughout each training session supports the concept of voluntary dehydration. Greenleaf and Sargent found that participants who were allowed to drink ad libitum took three hours to replace 50% of fluid lost during exercise (9). Voluntary dehydration is described across a wide variety of activities and sports in the literature (3, 7, 11, 12, 15, 27, 34). However, females in the current study, on average, were able to adequately replace fluid lost over the three days, refuting the voluntary dehydration phenomenon, suggesting females are more cognizant of sweat loss, and have better ability to replace sweat lost during exercise.

Guidelines recommend that athletes do not exceed a USG of 1.025 to maintain euhydration. A value of 1.026-1.029 indicates hypohydration and a value of >1.030 indicates severe hypohydration (31). Mean USG readings show males and females remained in a euhydrated state pre and post training throughout the three days. On average, females demonstrated better hydration status than males coming into training, with a difference in USG of .004. These findings are consistent with previous studies, where it is well documented that female athletes begin exercise more hydrated than males (28, 29, 30, 32). Although mean USG readings show male and female participants arrived and exited in a euhydrated state, 3% of males and 12% of females arrived in a state of hypohydration. Due to the observational nature of the study, these participants were allowed to enter training in this hypohydrated state and were not instructed to drink water to bring themselves to a euhydrated state.

Humans often are inclined to drink to satisfy personal thirst mechanisms. Winger et al. (33) found that drinking to thirst lacks objective measure and is often not enough to adequately replace fluid lost. However, the current study using self-reported thirst scales indicated that participants were satisfying thirst throughout the training sessions. The decrease in perceived thirst from pre to post training on all three days demonstrates athletes are finishing training less thirsty than before training. With participants remaining in a euhydrated state across the three training sessions, it could be argued that participants drinking to satisfy thirst is enough to maintain adequate fluid balance.

Sweat rate has been described to be a more accurate measure than thirst to replace fluid lost (33). In the present study, males had a decrease in sweat rate over the three days, and females had an increase in sweat rate (Table 3). In addition, males had a decreased rate of fluid consumption and females had an increase in fluid consumption over the three days, suggesting that both males and females utilize sweat rate to determine fluid consumption during training. Females have historically exhibited lower sweat rate than males (1). In the current study, males had a significantly higher sweat rate than females on day one, however females had a significantly higher sweat rate than males on day three. The discrepancies in sweat rate between males and females across the training sessions refute findings of previous studies (1, 18).

Perception of sweat loss is important so that adequate rehydration can take place. In this study, participants were asked to estimate the amount of sweat lost after training and then corrected by being shown how much sweat they actually lost. Both males and females underestimated by values that are representative of estimation data from various other sports (3, 18, 22, 30). Males and females significantly underestimated sweat loss by ~81% and ~64%, respectively, on day one. While both genders improved estimations from day one to day three, they still significantly underestimated sweat loss. Thigpen et al. (30) saw similar sweat loss estimations in university male and female basketball players, underestimating sweat lost by ~30% and ~63%, respectively. These improvements in sweat loss estimations suggest education on actual sweat loss will limit the difference between perceived sweat loss and measured sweat loss over multiple days. Although sweat loss underestimations were vast, participants remained in a euhydrated state across training sessions.

Observational field research has innate limitations. Due to the true observational status of this study, researchers observed a sample of university male and female rugby union players during standard training sessions. Limitations of this study include the variability of training schedules and session length between genders, variability of climate between training sessions within and between genders, relatively moderate ambient temperatures, and phases of the female menstrual cycle. Further research is needed to evaluate hydration status of male and female university rugby union players and perception of hydration status in higher ambient temperatures. Future studies should also compare hydration status of male and female athletes with a training plan with similar intensities to more accurately compare differences between genders.

In conclusion, the majority of participants remained in a euhydrated state throughout the three training sessions, maintaining proper body mass, USG and thirst levels. Open access to water provided by athletic trainers during university sports team practices is seemingly enough to adequately replace fluid lost. Although sweat loss can serve as a method of gauging fluid replacement, participants significantly underestimated sweat lost after each training session. This study has shown education of sweat lost can help improve measurements and therefore improve fluid replacement during training.

REFERENCES

1. Baker LB, Munce TA, Kenney WL. Sex differences in voluntary fluid intake by older adults during exercise. Med Sci Sports Exerc 37: 789-796, 2005.

2. Cahill N, Lamb K, Worsfold P, Headey R, Murray S. The movement characteristics of English Premiership rugby union players. J Sports Sci 31(3): 229-237, 2013.

3. Campbell S, Pritchett R, Cederburg K, Burnham T, Pritchett K. Fluid intake and sweat rate during hot yoga participation. Int J Exerc Sci 10(5): 721-733, 2017.

4. Cohen I, Mitchell D, Seider R, Kahn A, Phillips F. The effect of water deficit on body temperature during rugby. S Afr Med J 60: 11-14, 1981.

5. Cunniffe, B, Proctor, W, Baker, JS, and Davies, B. An evaluation of the physiological demands of elite rugby union using gps tracking software. J Strength Cond Res 23: 1195–1203, 2009.

6. Deutsch MU, Kearney GA, Rehrer NJ. Time-motion analysis of professional rugby union players during match-play. J Sports Sci 25(4): 461-472, 2007.

7. Godek SF, Bartolozzi AR, Godek JJ. Sweat rate and fluid turnover in American football players compared with runners in a hot and humid environment. Br J Sports Med 39: 205-211, 2005.

8. González-Alonso J, Mora-Rodríguez R, Coyle EF. Stroke volume during exercise: interaction of environment and hydration. Am J Physiol Heart Circ Physiol 278(2): H321-H330, 2000.

9. Greenleaf JE, Sargent F. Voluntary dehydration in man. J Appl Phys 20: 719-724, 1965.

10. Jones BL, O'Hara JP, Till K, King RFGJ. Dehydration and hyponatremia in professional rugby union players: a cohort study observing English premiership rugby union players during match play, field and gym training in cool environment conditions. J Strength Cond Res 29(1): 107-115, 2015.

11. Kilding AE, Tunstall H, Wraith E, Good M, Gammon C, Smith C. Sweat rate and sweat electrolyte composition in international female soccer players during game specific training. Int J Sports Med 30: 443-447, 2009.

12. Logan-Sprenger HM, Palmer MS, Spriet LL. Estimated fluid and sodium balance and drink preferences in elite male junior players during an ice hockey game. Appl Physiol Nutr Metab 36: 145-152, 2011.

13. MacLeod H, Sunderland C. Previous-day hypohydration impairs skills performance in elite female hockey players. J Med Sci Sports 22(3): 430-438, 2012.

14. Maughan RJ. Impact of mild dehydration on wellness and on exercise performance. Eur J Clin Nutr 57: S19-S23, 2003.

15. Maughan RJ, Merson SJ, Broad NP, Shirreffs SM. Fluid and electrolyte intake and loss in elite soccer players during training. Int J Sport Nutr Exerc Metab 14: 333-346, 2004.

16. McDermott BP, Anderson SA, Armstrong LE, Casa DJ, Cheuvront SN, Cooper L, Kenney WL, O'Connor FG, Roberts WO. National athletic trainers' association position statement: fluid replacement for the physically active. J Athl Train 52(9): 877-895, 2017.

17. Meir RA, Halliday AJ. Pre- and post- game body mass changes during an international rugby tournament: a practical perspective. J Strength Cond Res 19(3): 713-716, 2005.

18. O'Neal EK, Davis BA, Thigpen LK, Caufield CR, Horton AD, McIntosh JR. Runners greatly underestimate sweat losses before and after a 1-hr summer run. Int J Sport Nutr Exerc Metab 22: 353-362, 2012.

19. Oppliger RA, Magnes SA, Popowski LA, Gisolfi CV. Accuracy of urine specific gravity and osmolality as indicators of hydration status. Int J Sport Nutr Exerc Metab 15: 236-251, 2005.

20. Osterberg KL, Horswill CA, Baker LB. Pregame urine specific gravity and fluid intake by national basketball association players during competition. J Athl Train 44(1): 53-57, 2009.

21. Navalta JW, Stone WJ, Lyons TS. Ethical Issues Relating to Scientific Discovery in Exercise Science. Int J Exerc Sci 12(1): 1-8, 2019.

22. Passe D, Horn M, Stofan J, Horswill C, Murray R. Voluntary dehydration in runners despite favorable conditions for fluid intake. Int J Sport Nutr Exerc Metab 17: 284-295, 2007.

23. Peacock OJ, Stokes K, Thompson D. Initial hydration status, fluid balance, and psychological affect during recreational exercise in adults. J Sports Sci 29(9): 897-904, 2011.

24. Rothstein A, Adolph EF, Wills JH. Physiology of man in the desert. New York: Interscience Publishers; 1947.

25. Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. American college of sports medicine position stand- exercise and fluid replacement. Med Sci Sports Exerc 39(2): 377-390, 2007.

26. Sawka MN, Young AJ, Francesconi RP, Muza SR, Pandolf KB. Thermoregulatory and blood responses during exercise at graded hypohydration levels. J Appl Physiol 59(5): 1394-1401, 1985.

27. Shirreffs SM, Aragon-Vargas LF, Chamorro M, Maughan RJ, Serratosa L, Zachwieja JJ. The sweating response of elite professional soccer players to training in the heat. Int J Sports Med 26: 90-95, 2005.

28. Silva RP, Mundel T, Altoe JL, Saldanha MR, Ferreira FG, Marins JCB. Pre exercise urine specific gravity and fluid intake during one hour running in a thermoneutral environment – a randomized cross-over study. J Sports Sci Med 9: 464-471, 2010.

29. Stover EA, Petrie HJ, Passe D, Horswill CA, Murray B, Wildman R. Urine specific gravity in exercisers prior to physical training. Appl Physiol Nutr Metab 31: 320-327, 2006.

30. Thigpen LK, Green JM, O'Neal EK. Hydration profile and sweat loss perception of male and female division II basketball players during practice. J Strength Cond Res 28(12): 3425-3431, 2014.

31. Thomas DT, Erdman KA, Burke LM. American college of sports medicine joint position statement nutrition and athletic performance. Med Sci Sport Exerc 48(3): 543-568, 2016.

32. Volpe SL, Poule KA, Bland EG. Estimation of prepractice hydration status of national collegiate athletic association division I athletes. J Athl Train 44(6): 624-629, 2009.

33. Winger JM, Dugas JP, Dugas LR. Beliefs about hydration and physiology drive drinking behaviours in runners. Br J Sport Med 45(8): 646-649, 2011.

34. Zetou E, Giatsis G, Mountaki F, Komninakidou A. Body weight changes and voluntary fluid intakes of beach volleyball players during an official tournament. J Sci Med Sport 11: 139-145, 2008.