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Natural Training Hydration Status, Sweat Rates, and Perception of Sweat Losses during CrossFit Training

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ABSTRACT

International Journal of Exercise Science 9(5): 576-586, 2016. This study assessed 30 male and 20 female well-trained CrossFit (XF) athletes' natural hydration statuses, fluid intake, and absolute and estimated sweat losses during training sessions lasting 30-47 min. Participants provided a pre-workout urine sample for assessment of hydration by urine specific gravity (USG). Nude pre- and post-workout body mass and fluid intakes were measured to determine sweat losses. To evaluate perception of total sweat loss, participants were asked to estimate their total sweat loss to compare against actual sweat loss. Mean sweat losses did not exceed 1% body mass for men (range = 0.31-1.58% body mass) or women (range = 0.53-1.34% body mass), but sweat rates were nearly double for men (1.663 ± 0.478 L/h) vs. women (0.886 ± 0.274 L/h). Pre-exercise USG indicated euhydration for the majority of participants (32/50 samples = USG < 1.020). Only one participant had a USG >1.030. Mean sweat loss (0.746 ± 0.305 L) and mean sweat loss prediction (0.655 ± 0.404 L) were not significantly different ($p = 0.12$), and accuracy did not differ ($p = 0.44$) between men (-9.5 ± 53.7%) and women (+4.3 ± 70.9). No relationship ($r = 0.095$) was found between sweat loss prediction and fluid intake. Despite high sweat rates, no athletes lost greater than 2% body mass during a strenuous workout. This data combined with consistently normal pre-exercise USG and high fluid intake during exercise suggests ad libitum fluid intake is sufficient to ensure euhydration in the majority of XF participants.

KEY WORDS: Specific gravity, urine

INTRODUCTION

CrossFit (XF) is an organized exercise regimen that routinely incorporates Olympic and multi-joint lifts and intermittent high intensity exercise bouts. The movement has become increasingly popular with over 10,000 XF affiliates worldwide. Because of the intense nature of XF workouts, hydration status becomes pivotal for two primary reasons. The first concerns performance and the second exacerbation of external rhabdomyolysis.

Many of the exercises incorporated in a XF workout of the day (WOD) require repeated maximum effort or completion of technical movements. Dehydration has been found to impair performance during traditional resistance training (14, 15) and impair motor control (2, 10) which may be critical when completing repeated Olympic style lifts. Akin to the repetitive high intensity whole body exercise activities in XF, two recent studies also found decreased performance and increased heart rate and rate of perceived exertion during repeated 40-yard dash efforts in trained sprint-sport athletes (9, 11).

A second concern is that intense and often novel exercise regimens potentially increase risk of rhabdomyolysis. Concern for rhabdomyolysis in the XF population has been expressed in popular media periodicals (23), and the first published case report which included two men in their 30's completing the same XF workout was recently published (22). Rhabdomyolysis is the result of significant increases in levels of circulating creatine kinase and myoglobin from muscle damage often following new or taxing exercises (8). Other than "cola" colored urine, the non-clinical indicators of rhabdomyolysis, bi-lateral muscle swelling and muscle soreness (5), may be disregarded as normal, delayed onset muscle pain. Maintaining euhydration is likely critical to prevent further exacerbation of rhabdomyolysis (16).

A practical solution for XF athletes to optimize performance is to effectively rehydrate between training bouts, which traditional team sport athletes often fail to accomplish (12, 27). One explanation for the high prevalence of athletes arriving to practice dehydrated may be related to their inability to conceptualize sweat losses incurred. High urine specific gravity (USG) was displayed repeatedly before multiple practices in male and female Division II basketball players (27). The athletes also consistently underestimated the sweat loss volume incurred during practice, suggesting they had an inaccurate foundation on which to base their fluid intake needs between practices. Other well-trained athletes have also shown poor conceptualization when asked to estimate their sweat losses (17, 18).

To the authors' knowledge, no data exists concerning sweat loss norms, pre-exercise hydration status, or knowledge of XF athletes' ability to estimate sweat losses incurred during a WOD. The typically shorter duration of most XF workouts should mitigate absolute sweat losses; however, the high intensity nature of activities, open-air garage style facilities, and number of XF athletes who train more than once per day warrant examination of this growing population of recreational exercisers. Therefore, the purposes of this study were to assess the natural pre-workout hydration status of XF athletes, quantify sweat losses incurred during a XF training bout, and determine how accurately XF athletes assess their sweat losses.

METHODS

Participants

A sample of convenience that included 30 male (age 30.7 ± 9.9 y; 91.6 ± 12.9 kg) and 20 female (age 29.5 ± 8.3 y; 66.3 ± 9.0 kg) XF athletes were included in this investigation. A description of participant training history can be found in Table 1. Two XF affiliate owners agreed to allow data collection in their facilities and confirmed a privacy space would be available for assessing body mass and sweat loss estimation procedures. A description of the WOD activities is listed in Table 2. WODs ranged in time from 30-47 min. Investigators worked with the owners/coaches to ensure WODs during data collection would be representative of longer duration WODs. It was imperative that the dates be unannounced to XF athletes so spontaneous USG could be assessed, and XF athletes did not bias results by measuring their own changes in body mass before the investigation began. Only facility owners were made aware of the purpose of the study and when data collection would take place. The University of North Alabama Human Subject Committee approved all research procedures.

Table 1. Description of training and variables; n (%).

	Men (n = 30)	Women (n = 20)	Trained previous day (n = 23)	Did not train previous day (n = 27)	All (n = 50)
CrossFit participation					
0-6 months	11 (36.7)	4 (20.0)	10 (43.5)	5 (18.5)	15 (30.0)
6-12 months	4 (13.3)	3 (15.0)	4 (17.4)	3 (11.1)	7 (14.0)
12-24 months	8 (26.7)	6 (30.0)	6 (26.1)	8 (29.6)	14 (28.0)
24+ months	7 (23.3)	7 (35.0)	3 (13.0)	11 (40.7)	14 (28.0)
Days of training/week					
1-2	0 (0)	2 (10.0)	0 (0.0)	2 (7.4)	2 (4.0)
2-3	7 (23.3)	1 (5.0)	2 (8.7)	6 (22.2)	8 (16.0)
3-4	6 (20.0)	6 (30.0)	6 (26.1)	6 (22.2)	12 (24.0)
4-5	13 (43.3)	9 (45.0)	12 (52.2)	10 (37.0)	22 (44.0)
5+	4 (13.3)	2 (10.0)	3 (13.0)	3 (11.1)	6 (12.0)
Training hours/week					
0-5	4 (13.3)	4 (20.0)	3 (13.0)	5 (18.5)	8 (16.0)
5-10	17 (56.7)	14 (70.0)	14 (60.9)	17 (63.0)	31 (62.0)
10-15	7 (23.3)	1 (5.0)	3 (13.0)	5 (18.5)	8 (16.0)
15-20	1 (3.3)	1 (5.0)	2 (8.7)	0 (0.0)	2 (4.0)
20+	1 (3.3)	0 (0.0)	1 (4.3)	0 (0.0)	1 (2.0)
Train 2+ times per day	17 (56.6)	6 (30.0)	14 (60.9)	9 (33.3)	23 (46.0)
Days/week more than 1 training session per day	6 (20.0)	3 (15.0)	4 (18.0)	5 (18.5)	9 (18.0)
1-2	6 (20.0)	3 (15.0)	6 (26.1)	3 (11.1)	10 (20.0)
2-3	2 (6.7)	0 (0.0)	2 (8.7)	0 (0.0)	2 (4.0)
3-4	2 (6.7)	0 (0.0)	1 (4.3)	4 (15.0)	2 (4.0)
4-5	1 (3.3)	0 (0.0)	1 (4.3)	0 (0.0)	1 (2.0)
5+					

Protocol

XF athletes were greeted as they arrived at their gym during August and September. One facility was an open-air garage style gym while the other was fully enclosed and air-conditioned. The purpose of the study was explained and consent was obtained for those who chose to participate. Data collection took place at various times throughout the day. Participants were assessed during 10 separate training sessions. No participants were tested more than once. Personal preference was allowed for athletes in consideration for attire. Participants were asked to provide a pre-workout urine sample. Participants were allowed up to 15 min into the WOD to produce a urine sample if a pre-exercise sample could not be produced. Samples were analyzed for USG in duplicate using a manual refractometer (SUR-NE 300, Atago, Tokyo, Japan). Each sample was also analyzed in duplicate for urine color (1). The samples were used to assess pre-exercise hydration status. The National Athletic Trainers' Association guidelines (6) classifies USG of <1.020 as "minimal" dehydration, 1.021-1.030 as "significant" dehydration and, >1.030 as "serious" dehydration. We further subdivided our USG classification results to include participants that ranged from 1.020-1.024 and 1.025-1.029 to provide additional categorical description. Any samples provided after an initial body mass assessment were measured for mass to be used in calculation of sweat losses. All samples were disposed of immediately after analysis.

Table 2. Description of workouts of the day (WOD) activities, time of day, duration and average WBGT.

WOD 1	WOD 2	WOD 3
20 wall balls · 20 sit-ups · 20 box jumps · 20 push-ups · 20 hang clean (135/95 lbs) · 20 double unders · 20 thrusters · 20 pull-ups · 20 overhead squats (95/65 lbs) · 20 kettlebell swings (15/11 lbs) · 20 push press (95/65 lbs) · 20 Dips · 20 Sumo deadlift hi pull (95/65 lbs) · 20 burpees · 20 back squats (135/95 lbs) · 20 glute-hamstring developers · 20 walking lunges · 20 dead lifts (135/95 lbs) · 20 knees to elbows · 20 front squats (135/95 lbs)	Back squat (build to tough set of 5 in first 12 minutes) · The remainder of the workout was to complete as many rounds as possible of 15 thrusters · 15 burpees · 15 ring rows · 15 pull-ups · 1000 m row ·15 chest to bar pull-ups	· 1 deadlift · 15 medball cleans · 15 ring rows · 15 glute-hamstring developer sit-ups · 15 hip extensions · 4 x 5 snatch grip deadlift · 20 shoulder to overhead (155/105 lbs) · 400 m run · 20 power snatches (135/95 lbs) · 400 m run · 20 overhead squats (115/75 lbs) · 20 dead lifts (225/155 lbs) · 400 m run · 20 hang cleans (185/125 lbs) · 400 m run

Time	n	Min	WBGT °C	Time	n	Min	WBGT °C	Time	n	Min	WBGT °C
0545	3	37	19.8	0510	7	30	17.1	1600	3	43	24.8
0830	7	39	21.4	0600	4	30	17.1	1700	2	47	23.6
1200	6	40	21.4	1200	8	30	16.2				
				1630	4	30	16.6				
				1730	6	30	16.4				

Each participant was weighed in the nude on a digital scale (Tanita BWB-800. Tokyo, Japan) before the WOD, but was not allowed to see their body mass. The investigators supplied each participant with one chilled 500 mL bottle of water to drink ad libitum during their WOD with more chilled bottles available upon request. Pre- and post- WOD bottle mass was measured to the nearest 2 g and change in bottle mass was used when determining total sweat losses. Wet bulb globe temperature (WBGT) was measured and averaged to describe environmental conditions. A short questionnaire was given at the conclusion of each WOD. The questionnaire asked participants to describe their level of thirst, pre-exercise fluid intake, and estimated hydration status. Then participants were taken to a private area and asked to estimate the amount of sweat they believed they lost during their WOD. Individuals were given ten, 250 mL bottles of water and were instructed to select the combination of bottles representative of the sweat they believed they lost during the workout. Following sweat loss estimations, participants toweled off and post-exercise body mass was assessed.

Statistical Analysis
Independent t-tests were used to determine if differences in dependent variables differed by gender or between subjects who had or had not completed a training session in the previous 24 hours. Paired t-tests were used to compare sweat loss estimations to actual sweat losses and descriptive data including means, standard deviations, and frequency counts are reported when appropriate. A p-value ≤ 0.05 was deemed significant in all analyses.

RESULTS

One male and female participant reported feeling "very dehydrated" prior to the WOD and only 2 participants did not drink at least 500 mL of fluid in the 3 hours prior to exercise (Table 3). Pre-exercise USG indicated euhydration for the majority of participants (32/50 samples = USG < 1.020) and approached significance between genders (p = 0.06) but not between participants who had exercised the previous day and those who had not (p = 0.523). Ten men and 5 women had USG between 1.020 and 1.024. Two men had USG levels between 1.025 and 1.029. Only one female participant had a USG greater than 1.030. Urine color did not differ between genders (p = 0.12).

Table 3. Pre-exercise fluid intake and hydration indices; n (%) or mean ± SD.

	Men (n = 30)	Women (n = 20)	Trained previous day (n = 23)	Did not train previous day (n = 27)	All (n = 50)
Fluid in past 3 hours					
(mL)	1 (3.3)	1 (5.0)	0 (0.0)	2 (7.4)	2 (4.0)
0	6 (20.0)	3 (15.0)	5 (21.7)	4 (14.8)	9 (18.0)
500	9 (30.0)	7 (35.0)	8 (34.8)	8 (29.6)	16 (32.0)
750	8 (26.7)	6 (30.0)	5 (21.7)	9 (33.3)	14 (28.0)
1000	2 (6.7)	2 (10.0)	3 (13.0)	1 (3.7)	4 (8.0)
1250	4 (13.3)	1 (5.0)	2 (8.7)	3 (1.1)	5 (10.0)
1250+					
Estimated hydration					
status	1 (3.3)	1 (5.0)	0 (0.0)	2 (7.4)	2 (4.0)
Very dehydrated	15 (50.0)	5 (25.0)	9 (39.1)	11 (40.7)	20 (40.0)
Moderately dehydrated	12 (40.0)	13 (65.0)	14 (60.9)	11 (40.7)	25 (50.0)
Moderately hydrated	2 (6.7)	1 (5.0)	0 (0.0)	3 (11.1)	3 (6.0)
Very Hydrated					
Thirst Rating*	5.8 ± 1.8	5.8 ± 2.0	6.0 ± 1.7	5.7 ± 2.0	5.8 ± 1.8
USG	1.017 ± 0.007	1.013 ± 0.009†	1.015 ± 0.008	1.016 ± 0.008	1.015 ± 0.008
Urine color (1-8)	4.0 ± 2.0	3.4 ± 2.1	3.3 ± 2.3	4.1 ± 1.8	3.8 ± 2.1

* 1 = "Not thirsty at all"; 10 = "Severely thirsty"; † = p = 0.064

Sweat loss and fluid intake data are presented in Table 4. Mean sweat losses did not exceed 1% body mass for men (range = 0.31-1.58% body mass) or women (range = 0.53-1.34% body mass). No participant lost more than 2% of body mass. Sweat rates were nearly double for men vs. women with rates ranging from 300-2,660 mL/h. Despite these differences in sweat rates, women consumed equivalent volumes of fluid to men and exceeded their own sweat losses with fluid intake during training alone (Table 4).

Table 4. Description of sweat losses and fluid intake.

	Men (n = 30)	Women (n = 20)	Trained previous day (n = 23)	Did not train previous day (n = 27)	All (n = 50)
Sweat loss					
Absolute (L)	0.894 ± 0.284	0.525 ± 0.174†	0.788 ± 0.300	0.707 ± 0.312	0.744 ± 0.306
Rate (L/h)	1.663 ± 0.478	0.886 ± 0.274†	1.289 ± 0.469	1.340 ± 0.600	1.316 ± 0.539
% body mass	0.99 ± 0.32	0.78 ± 0.23†	0.96 ± 0.32	0.86 ± 0.29	0.91 ± 0.31
Fluid intake (L)	0.592 ± 0.237	0.565 ± 0.211	0.590 ± 0.195	0.574 ± 0.251	0.581 ± 0.225
% replacement	75.1 ± 46.8	127.8 ± 82.1†	88.1 ± 53.9	103.0 ± 78.0	96.6 ± 68.0

† = $p < 0.05$ between genders

Individual and mean sweat losses and sweat loss estimations are presented by gender in Figure 1. Overall, mean sweat loss (0.746 ± 0.305 L) and mean sweat loss prediction (0.655 ± 0.404 L) were not significantly different (p = 0.12), and accuracy did not differ (p = 0.44) between men (-9.5 ± 53.7%) and women (+4.3 ± 70.9). While the mean differences between estimated and actual sweat losses are minimal, the large standard deviations are attributed to a few participants that greatly over or underestimated. Only 4 men and 4 women exhibited estimation error by more than 500 mL. Participants who stated they previously measured change in weight before and after a WOD to determine fluid loss (n = 13) showed no significant difference (p = 0.97) in estimation accuracy than those who had not weighed previously (-3.3 ± 47.9 and -4.1 ± 65.1 respectively). No correlation was found (r = 0.095) between sweat loss prediction and WOD fluid intake

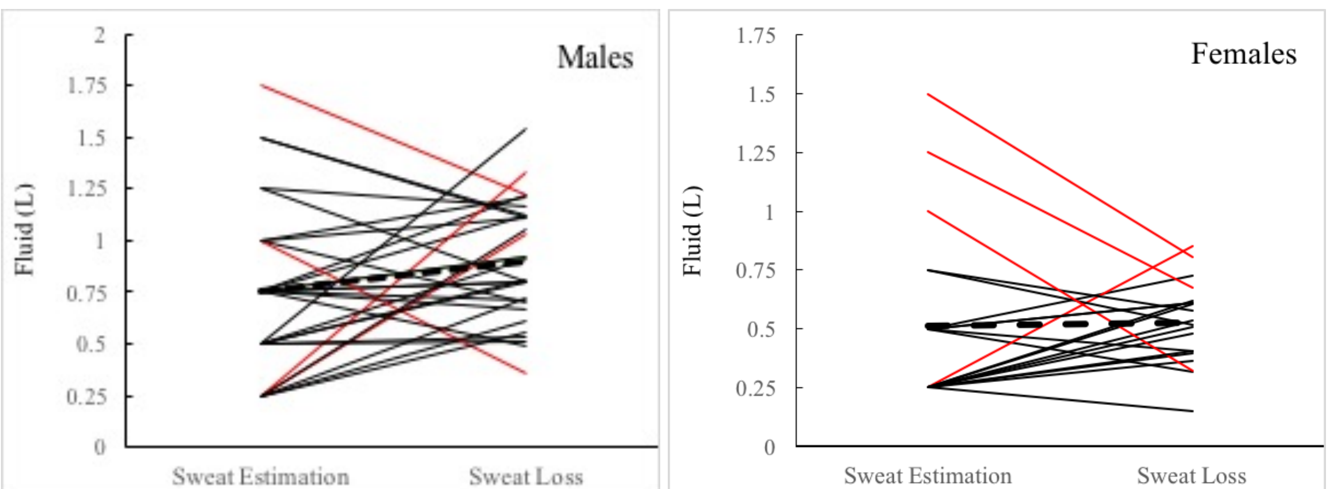

Figure 1. Sweat loss estimation accuracy displayed by individual (solid black lines) and gender means (dashed lines). Red lines represent estimations with greater than 500 mL of error in estimation.

DISCUSSION

XF is arguably the largest fitness movement in the last decade, but the hydration dynamics of this population have never been examined to our knowledge. The intensity, high variation in training modalities, and various potential training environments make it difficult to compare this population of recreational exercisers' hydration needs to those training in more traditional fitness facilities. This investigation examined the natural hydration statuses, fluid intake practices, sweat losses, and accuracy of sweat loss estimation of XF exercise participants.

Nearly half of the participants reported regularly training twice per day with some commencing in twice daily training up to 5 days per week (Table 1). Additionally, 21 participants were training in an open non-air conditioned facility with data collection taking place in late summer. Despite these factors the majority of participants began exercise in a state of euhydration based on USG and urine color and severe dehydration was not common (Table 3). Stover et al. (25) examined spontaneous USG of 329 recreational exercisers entering traditional fitness facilities and found; male USG (1.020 ± 0.007) was higher than female USG (1.017 ± 0.008), and only 3% of gym patrons had USG levels ≥ 1.030. These trends were very similar to that displayed in the current study. The only other study we are aware of that assessed pre-exercise hydration status in recreational exercisers was conducted by Peacock et al. (21). At a traditional fitness facility, urine osmolality (698 ± 288 mOsmol/kg) was assessed in a very similar demographic sample (31 men and 21 women; age 36 ± 12 y) when compared to the current investigation. The authors did not report percentages of severe dehydration, only that 37% of gym members had urine osmolality > 900 mOsmol/kg making comparisons somewhat difficult. These findings support that while the training paradigms XF athletes participate in may be more technical and of higher intensity than recreational exercisers, XF athletes do not exhibit the more pronounced states of dehydration reported before practice in team sport athletes of various competition levels (13, 26, 27).

Multiple variables possibly explain the high prevalence of euhydration based on USG values reported. The 30-47 min WODs were specifically incorporated by BOX coaches to exemplify a longer duration training bout during this study. It is likely a shorter WOD was completed during previous training sessions for most participants. Approximately 60% of our participants were also training in an air conditioned facility suggesting significant fluid deficit was not likely incurred during their previous exercise bout.

The similarity in our participants based on gender distribution and age to Peacock et al. (21) provide a great comparison to traditional fitness facility participants' expected sweat rates. Additionally, the mean body mass in Peacock et al. (21) (80.7 ± 15.9 kg) was nearly identical compared to the current investigation sample (81.5 ± 16.9 kg). Including warm-up/cool down and all voluntary exercise of the traditional gym patrons, exercise session duration equaled 70 ± 23 min. Despite nearly a 30+ minute longer duration in the traditional gym patrons' workout, absolute sweat volume (794 ± 391 mL) was similar to outcomes in the current study (Table 4). The comparable body masses also indicate sweat loss as % body mass likely match those of XF participants. However, the shorter duration XF workouts resulted in much higher sweat rates (9.3 versus 16.1 mL/kg/h) indicating traditional gym patrons' sweat production norms cannot be extrapolated to XF exercisers.

USG was lower for women versus men in both the current study (Table 3) and Stover et. al. (25). The current authors feel these statistical differences might be somewhat trivial in a practical sense, particularly due to the high USG variance. However, fluid intake differences between genders is intriguing. Women exhibited lower pre-exercise USG and experienced considerably reduced sweat losses but consumed the same volume of fluid during the WOD, replacing fluid at a rate ~28% greater than sweat losses versus under replacement of ~25% for men (Table 4). Elite female basketball players (4) displayed markedly lower USG than men (19) before actual competition, but these gender differences seem to be mitigated when similar rigorous training is occurring (27). The trend for women to consume exceedingly greater percentage of sweat loss has been exhibited both during repeated bouts of endurance exercise with rest periods (3) and for a 24-h period following a 1 hour run (17). The tendency for women to overconsume fluids in regards to sweat losses relative to men is not well understood, but anecdotally the female XF athletes voiced a greater awareness or concern about their hydration status to investigators. However, the participant with the highest urine color (7), the only USG (1.033) exceeding the "severe" 1.030 classification as defined by the National Athletic Trainers' Association (6), and one of few participants that reported drinking nothing in the 3 hours prior to training was a female. She was also the only female to report believing she was "very dehydrated" before her WOD indicating a self-awareness of her atypical hydration status compared to the rest of the sample.

Endurance athletes have consistently displayed a prevalence to underestimate sweat losses regardless of gender or environment (17, 18, 20). Collegiate basketball players have also exhibited this trend during longer, lower intensity practices with frequent breaks (27). However, during a short duration repeated sprint and shuttle running conditioning session (27) that would be more akin to the WODs used in the current study players' estimations were much closer to their actual sweat losses. Likewise, very little difference in mean estimation and actual sweat losses for both genders were found in the current study (Figure 1).

We do not believe that the more accurate estimations of sweat losses versus those found in other studies were due to implementation of suggested practices of determining sweat losses from weighing oneself before and after practice (6, 24). Thirteen participants (26%) had reported weighing themselves before and after a training session, but this group displayed no difference in variance of estimation accuracy than individuals who had not previously weighed themselves. We attribute the improved sweat loss estimation accuracy to two factors. The first was a much lower underestimation window was possible due to the decreased absolute volume of sweat loss in comparison to past studies (17, 18, 20, 27). The second rationale we propose is that the high sweat rates, not necessarily volume, similar to the short, high intensity conditioning basketball session previously described (27) potentially led to less conservative sweat loss estimates. Sweat accumulation on participants' skin and in clothing were highly visible. In comparison, the endurance athletes (17, 18, 20) that consistently underestimated their sweat losses in past studies were running outdoors resulting in greater convective related sweat evaporation that possibly led to a perception that sweat losses were not as significant as in the current study.

While most participants' estimations of sweat losses were accurate, several athletes vastly under- or overestimated sweat losses. Having confident recognition of sweat losses can possibly help the small percentage of athletes that fail to rehydrate adequately between WODs improve their hydration strategies. It should also be noted that recognition of true sweat loss volume is beneficial for avoiding overconsumption of fluid during and after exercise. This may be particularly important to small, female exercisers with very low sweat rates.

This study has multiple limitations. The first is that fluid consumption was only monitored during activity and not between training bouts. Chilled water was the only beverage available to the participants and may have impacted the amount of fluid consumed because of personal preference. Additionally, multiple factors make it difficult to predict sweat losses for the individual, even with consideration for gender. XF training activities are extremely variable by design and can differ greatly in duration and environment versus patrons that engage in similar traditional exercise facility training modalities (e.g. traditional strength training or spin classes) in maintained temperate conditions. It has been recently proposed that USG may not be a valid indicator of hydration status unless it is incorporated after a prolonged period of fluid homeostasis (7). No consideration was made on USG concerning time of day the sample was taken or possible menstrual cycle phase interaction for female participants. It is also possible that the athletes increased their fluid consumption because they were under observation. Further examination is recommended for XF athletes who practice only in open-air, garage style facilities during hot seasons.

The current study reveals that XF participants exhibit considerably increased sweat rates in comparison to results of other studies examining traditional gym patrons, but shorter WOD durations result in comparable absolute sweat loss volume. Despite high sweat rates, no athletes lost greater than 2% body mass during a strenuous WOD. This data combined with pre-exercise USG values and high fluid intake during exercise suggests ad libitum fluid intake is sufficient to ensure euhydration in the majority of XF participants training once per day. Only one "open" facility was assessed, but WBGT ranged from 20-25 °C during WODs. Combined with the high number of participants that reported training more than once per day these factors highlight the potential for significant daily absolute sweat losses. For XF participants training under such circumstances, fluids should be readily available during training and fluid prescription between training sessions should be based on incurred sweat loss assessed by change in body mass from pre- to post-exercise. Multiple observations and representation of sweat loss volume in tangible terms (e.g. present bottles of water equivalent to sweat losses) may be useful in helping athletes conceptualize sweat losses and develop appropriate rehydration strategies. USG may also be a simple, objective indicator for XF coaches to detect athletes that fail to rehydrate adequately.

REFERENCES

1. Armstrong LE. Performing in Extreme Environments. Champaign, IL: Human Kinetics; 2000.

2. Baker LB, Dougherty KA, Chow M, Kenney WL. Progressive dehydration causes a progressive decline in basketball skill performance. Med Sci Sports Exerc 39(7):1114-23, 2007.

3. Baker LB, Munce TA, Kenney WL. Sex differences in voluntary fluid intake by older adults during exercise. Med Sci Sports Exerc 37(5):789-96, 2005.

4. Brandenburg JP, Gaetz M. Fluid balance of elite female basketball players before and during game play. Int J Sport Nutr Exerc Metab 22(5):347-52, 2012.

5. Brudvig TJ, Fitzgerald PI. Identification of signs and symptoms of acute exertional rhabdomyolysis in athletes: A guide for the practitioner. Strength and Cond J 29(1):10-4, 2007.

6. Casa DJ, Armstrong LE, Hillman SK, Montain SJ, Reiff RV, Rich BS, Roberts WO, Stone JA. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. J Athl Train 35(2):212-24, 2000.

7. Cheuvront SN, Kenefik RW, Zambraski EJ. Spot urine concentrations should not be used for hydration assessment: a methodology review. Int J Sport Nutr Exerc Metab 25(3):293-97, 2015.

8. Cleary M. Predisposing risk factors on susceptibility to exertional heat illness: clinical decision-making considerations. J Sport Rehabil 16(3):204-14, 2007.

9. Davis J-K, Laurent CM, Allen KE, Green JM, Stolworthy NI, Welch TR, Nevett ME. Influence of dehydration on intermittent sprint performance. J Strength Cond Res 29(9):2586-93, 2015.

10. Distefano LJ, Casa DJ, Vansumeren MM, Karslo RM, Huggins RA, Demartini JK, Stearns RL, Armstrong LE, Maresh CM. Hypohydration and hyperthermia impair neuromuscular control after exercise. Med Sci Sports Exerc 45(6):1166-73, 2013.

11. Gann JJ, Green JM, O'Neal EK, Renfroe LG, Andre TL. Effects of hypohydration on repeated 40-yd sprint performance. J Strength Cond Res 30(4) 901-09, 2016.

12. Godek SF, Bartolozzi AR, Peduzzi C, Heinerichs S, Garvin E, Sugarman E, Burkholder R. Fluid consumption and sweating in National Football League and collegiate football players with different access to fluids during practice. J Athl Train 45(2):128-35, 2010.

13. Hamouti N, Del Coso J, Estevez E, Mora-Rodriguez R. Dehydration and sodium deficit during indoor practice in eliete European male team players. Eur J Sport Sci 10(5):329-36, 2010.

14. Judelson DA, Maresh CM, Farrell MJ, Yamamoto LM, Armstrong LE, Kraemer WJ, Volek JS, Spiering BA, Casa DJ, Anderson JM. Effect of hydration state on strength, power, and resistance exercise performance. Med Sci Sports Exerc 39(10):1817-24, 2007.

15. Kraft JA, Green JM, Bishop PA, Richardson MT, Neggers YH, Leeper JD. Impact of dehydration on a full body resistance exercise protocol. Eur J Appl Physiol 109(2):259-67, 2010.

16. Line RL, Rust GS. Acute exertional rhabdomyolysis. American family physician 52(2):502-6, 1995.

17. O'Neal EK, Caufield CR, Lowe JB, Stevenson MC, Davis BA, Thigpen LK. 24-h fluid kinetics and perception of sweat losses following a 1-h run in a temperate environment. Nutrients 6:37-49, 2014.

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(5):353-62, 2012.

19. 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):53-7, 2009.

20. 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(3):284-95, 2007.

21. 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.

22. Rathi M. Two cases of CrossFit-induced rhabdomyolysis: A rising concern. Int J Medical Students 2(3):132-43, 2014.

23. Robertson E. CrossFit's Dirty Little Secret. The Huffington Post, 2013. http://www.huffingtonpost.com/eric-robertson/crossfit-rhabdomyolysis_b_3977598.html.

24. 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):377-90, 2007.

25. 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(3):320-7, 2006.

26. Stover EA, Zachwieja J, Stofan J, Murray R, Horswill CA. Consistently high urine specific gravity in adolescent American football players and the impact of an acute drinking strategy. Int J Sports Med 27(4):330-5, 2006.

27. 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):3425-31, 2014.