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Abstract

The purpose of this manuscript is to assess hydration status of elite young sailing athletes during World Championship competition. 12 young elite male Laser Class sailors (age: 15.8±1.1 y, height: 1.74±0.1 m, weight: 65.1±1.5 kg, body fat: 12.5±3.1%, training experience: 7.0±1.2 y) participated in this descriptive study. After three-day baseline bodyweight measurements, hydration status was assessed via pre- and post-race body weights, urine specific gravity, and thirst ratings via a visual analog scale during 4 consecutive days of racing. Measurements and data collection took place at the same time each racing day, with mean environmental temperature, humidity, and wind speed at 23.0±0.8 ^{o}C, 64-70% and 9±1 knots, respectively. Average racing time was 130±9 min. Body weight was significantly decreased following each race-day as compared to pre-race values (day 1: -1.1±0.2, day 2: -2.5±0.1, day 3: -2.8±0.1, and day 4: -3.0±0.1% of body weight; P<0.05). The participants exhibited dehydration of -2.9±0.2 and -5.8±0.2% of body weight before and after the 4th racing day as compared to the 3-day baseline body weight. Urine specific gravity (pre – post → day 1: 1.014-1.017; day 2: 1.019-1.024; day 3: 1.021-1.026; day 4: 1.022-1.027) and thirst (pre – post → day 1: 2.0-5.2; day 2: 3.2-5.5; day 3: 3.7-5.7; day 4: 3.8-6.8) were also progressively and significantly elevated throughout the four days of competition. The data revealed progressive dehydration throughout four consecutive days of racing as indicated by decreased body weight, elevated urine concentration, and high thirst.

Key Words: Nutrition, Sport, Exercise Performance, Rehydration, Thirst, Sailing

Introduction

Maintaining fluid homeostasis is vital for optimal athletic performance in both youth and adults. The loss of plasma volume (hypovolemia) concomitant with dehydration results in cardiovascular and thermoregulatory strain due to elevation of heart rate and decrease in cardiac output, ultimately impeding the body's ability to dissipate heat (Gonzalez-Alonso, Mora-Rodriguez, Below, & Coyle, 1995, 1997). Dehydration as little as -2% body weight has been shown to adversely impact performance as well as cognitive skill (Casa et al., 2010; Sawka et al., 2007). Despite these deleterious effects, athletes regularly ingest less fluid than adequate to maintain euhydration, even when provided ad libitum drinking. One of the first studies to show this phenomenon was conducted by Greenleaf and Sargent. The authors termed inadequate fluid intake as voluntary dehydration (Greenleaf & Sargent, 1965). In a more recent study, Passe and colleagues found that experienced runners only replaced 30% of their total sweat loss during a 16-km race despite free access to fluid. The runners also significantly underestimated sweat loss throughout the race indicating inaccurate perceptual measurement of dehydration level during competitive events (Passe, Horn, Stofan, Horswill, & Murray, 2007). Moreover, recent studies have indicated that the majority of athletes begin competitive events hypohydrated, potentially exacerbating the effects of voluntary dehydration experienced during the event. Arnaoutis et al. examined pre-training hydration status of young athletes via urine specific gravity (USG) and urine color and found that more than 2/3 of participants began their workout in a sub-optimal hydration state (Arnaoutis et al., 2015). Stover et al. found similar results when examining American high school football players. In this study, 70% of the 46 subjects arrived to training hypohydrated as indicated by urine specific gravity greater than 1.020 (Stover, Zachwieja, Stofan, Murray, & Horswill, 2006).

Although studies indicate a high prevalence of voluntary dehydration, some researchers suggest that athletes rehydrate adequately throughout the rest of the day following a competitive event. Costill and Fink dehydrated 12 participants by approximately -2.1 kg body weight each day for 5 consecutive days while providing ad libitum fluid intake and controlling food intake. Despite repeated daily bouts of exercise resulting in dehydration, participants maintained proper hydration as indicated by constant pre-trial body weight for each successive day (Costill & Fink, 1974). Similarly, in 2014 Ross and colleagues examined the rehydration practices of elite cyclists during two multi stage events using body mass change and fluid consumption recall. The researchers did not record any significant changes in hydration status from one stage to the next (Ross et al., 2014). These data indicate effective day-to-day rehydration practices following successive bouts of exercise-induced dehydration. However, Godek et al. reported sustained levels of dehydration in college football players with ad libitum fluid intake throughout six days of pre-season training in a hot and humid environment as measured via changes in body mass and plasma volume as well as urine specific gravity and electrolytes. In this particular study, athletes arrived to training hypohydrated and remained in the same state throughout data collection (Godek, Godek, & Bartolozzi, 2005). Similarly, Yeargin and her colleagues found that adolescent football players remained hypohydrated between consecutive training days as measured via urine osmolality and thirst indicating insufficient hydration habits when not training (Yeargin et al., 2010). The inconsistent results seen in previous literature could be attributed to the absence of a standard measurement of hydration status. The utilization of a consistent measurement is needed to further elucidate rehydration practices of athletes after competitive events. Apart from the previously mentioned studies, there is a lack of literature directly investigating progressive hydration status during multi-stage elite training or competitive events.

Olympic Laser Class sailing is a physically demanding sport placing significant thermoregulatory strain on the body in warm and humid conditions (Blackburn, 2015; Tan, 2000). Neville and colleagues investigated thermoregulatory demands of sailing during America's Cup Yacht Racing. The researchers reported mean core and skin temperatures via ingested temperature sensor capsules and wireless adhesive temperature sensors of 38.1±0.3°C and 34.4±0.5 °C, respectively. Mean sweat loss during the race was 2.24±0.89 L equivalent to a sweat rate of 1.34±0.58 $L \cdot h^{-1}$ (Neville, Gant, Folland, 2010). The sport also requires high levels of concentration as athletes are required to make rapid tactical decisions. Additionally, athletes remain on the water for long durations with limited access to fluids due to the nature of the sport and lack of space in the boat (Allen & De Jong, 2006). The small amount of research specific to sailing performance and nutrition indicates that sailors fail to prevent dehydration greater than -2% of body weight throughout competition (Slater & Tan, 2007). Also, elite sailors demonstrate a lack of knowledge regarding sports nutrition, including guidelines for fluid consumption during exercise (Legg et al., 1997). This lack of knowledge exacerbated by physically demanding race conditions and no drinking opportunities could reasonably lead to significant dehydration, thereby negatively effecting performance. Considering the multi-day structure of typical sailing competitions, athletes could experience substantial performance decrements and even compromise their safety.

Based on previous studies, athletes often dehydrate during competitive events, a practice that could impair performance and increase the risk of heat injuries. In addition to exercise-induced dehydration, athletes often arrive to competitive events hypohydrated. However, limited and conflicting data exists on hydration status throughout multi-day events, especially in competitive sailing. Therefore, the purpose of this study was to investigate the hydration status of elite young sailing athletes during a 4-day World Championship competition.

Methods

Twelve young elite male sailors participated in the study (15.8±1.1 y, 65.1±1.5 kg, 1.74± 0.1 m). All participants were trained sailors (>15 h of boat and dryland training per week) for 7.0 ±1.2 y with experience in national and international competitions as members of the Greek national sailing team. Eligibility criteria for inclusion in the study included participation in the Junior Sailing World Championship and absence of any metabolic, cardiovascular, or renal disease. All participants and their legal guardians gave written informed consent prior to the start of the study. The athletes knew that they were participating in nutritional study, but were unaware of the objectives related to fluid intake and hydration status. The study was conducted in accordance with the declaration of Helsinki ethical principles and was approved by an Independent Ethics Committee. All participants had a normal body mass index (BMI: 21.5±1.9 $kg \cdot m^{-2}$) for age (Cole, Flegal, Nicholls, & Jackson, 2007). Body fat (12.5±3.1%) was assessed the day before their departure by dual-energy X-ray absorptiometry (model DPX-MD, Lunar Corp., Madison, WI, USA). Baseline body weight was established as the mean value of the last three days before departure and two days prior to the first day of competition (Tanita bc-601).

Data collection took place in Medemblic, Netherlands during the Junior Sailing World Championship in August 2015. Morning body weight with minimal clothing (underwear) was recorded to the closest 100 g (Tanita bc-601). During four consecutive racing days in the competition body weights, urine samples, and thirst ratings via a visual analog scale (VAS)(Rolls et al., 1980) were collected pre- and post-race. VAS measurements were scored in mm and data were presented as percent of extremely thirsty (125 mm). All the aforementioned measurements took place approximately 20 minutes before the athletes were transported to the starting line and immediately upon their return to the shore after the end of the race. No fluids were ingested between pre-race measurements and the end of the race. Environmental temperature and humidity during days 1-4 were 22, 23, 23, and 24 ^{o}C and 67.5%, 67.5%, 62.5%, and 67.5%, respectively. Mean wind speed during the four days of competition was 16.6±1.9 $km \cdot h^{-1}$ (9±1 knots). Athletes competed daily, on average for 130±9 min between 11:00 am and 4:00 pm depending on the weather conditions. Urine samples were analyzed fresh for specific gravity (USG) via a handheld refractometer (ATAGO SUR-NE, Tokyo, Japan).

Rehydration practices and nutrition patterns were ad libitum and no nutritional guidelines including rehydration strategies were provided to the athletes for the competition. Timing and content of nutrient intake were consistent throughout the competition. Every day the athletes consumed at the hotel a buffet style breakfast with eggs, bacon, sausage, yogurt, and bread products from 7:30-8:00 AM. Upon arrival to the marina (10:00-10:30 AM) athletes consumed a large snack before pre-race measurements consisted of water, sports drinks, energy bars, fruit, yogurt, and sandwiches. No food or fluids were ingested during competition. Athletes consumed another snack immediately after post-race body weight. Around 7:00 PM athletes consumed dinner mainly composed of a salad and a main plate that included rice, pasta or potatoes and meat (beef, pork, chicken or fish). After dinner and prior to sleep, athletes had access to water, juices, sports drinks, fruits, yogurts, and cereal bars in their rooms.

Data are presented as means ± standard deviation. Repeated measures analysis of variance (ANOVA) with Bonferroni correction was used to examine significance between pre- and post-race values exhibited day 1 through day 4. A one-way repeated measures ANOVA with Bonferroni correction was used to examine significance between pre-race indices and baseline from day 1 pre-race values. Significance was accepted at the 0.05 level. Statistical analyses were performed using SPSS 23 (SPSS Inc, Chicago, IL).

Results

Figure 1A depicts body weight values for the 3-day baseline prior to the competition as well as before and after days 1-4 of the races. Figure 1B shows the percent of body weight change in comparison to the 3-day baseline. The data indicated significant decrease in body weight following each race day as compared to pre-race values for the days 1, 2, 3, and 4 by -1.1 ±0.2, -2.5±0.1, -2.8±0.1, and -3.0±0.1% of body weight, respectively. Pre-race body weight was also significantly and progressively decreased on days 2, 3, and 4 as compared to three-day baseline value, indicating progressive dehydration. The highest degree of dehydration, compared to 3-day baseline body weight, was observed on the 4th racing day (pre: -2.9±0.1 and post: -5.8±0.2% of body weight).

Figure 2A depicts the pre- and post-race USG for days 1-4 of competition. All athletes were well hydrated prior to the first race as indicated by their USG (<1.020 for all subject), however, their values were significantly elevated following each race-day as compared to pre-race values (Fig 2A). Pre-race USG values for days 2, 3, and 4 were all significantly higher as compared to pre-race USG for day 1. Interestingly, 3, 5, and 11 out of the 12 athletes had USG greater than 1.020 prior to the race for days 2, 3, and 4, respectively. Figure 2B presents the pre- and post-race thirst data, expressed as percent of maximal rating. Thirst was significantly increased as compared to pre-race values for each day (Fig 2B). Pre-race thirst ratings for days 2, 3, and, 4 were all significantly higher than day 1 pre-race thirst.

Discussion

In the current study, the hydration status of elite sailors was studied throughout the 4-day Junior Sailing World Championship. The main finding of the study was the presence of progressive dehydration based on decreased body weight, as well as elevated USG and thirst. Previous studies have suggested that athletes dehydrate during competition, however, to our knowledge this is the first study to show the phenomenon occurring progressively throughout a multi-day competition.

Interestingly, progressive increase in thirst throughout the four days of competition did not prompt athletes to increase their fluid intake and replenish their water losses. Although pre-race thirst increased each day as compared to the previous day of competition, urine and body weight measures indicated that athletes did not adequately replace water loss. It has been suggested that athletes competing in the heat should replenish water loss guided only by thirst (Noakes, 2010), even though the topic is quite controversial (Armstrong, Johnson, & Bergeron, 2016). However, our data indicate, that relying solely upon thirst to maintain optimal hydration is not effective, especially in events spanning multiple days. The body weight and USG data indicate the sailors were becoming hypohydrated with concomitant increases in thirst sensation. These findings are in agreement with Arnaoutis et al., which found that ad libitum fluid intake did not prevent dehydration in 54 of 66 (82%) young soccer players that started their practice with USG greater than 1.020 during a summer camp (Arnaoutis et al., 2013). Two studies have examined change in performance and physiological markers in young athletes with similar values of dehydration exhibited in the current study. Both found decreases in performance and physiological markers associated with poor exercise performance (Dougherty, Baker, Chow, & Kenney, 2006; Wilk, Meyer, Bar-Or, & Timmons, 2014). Unfortunately, due to the continuously changing nature of wind and water conditions in sailing, performance is extremely difficult to be evaluated especially during competition.

Few studies have examined hydration markers in sailing during a multi-day event. The sport of sailing is highly competitive and requires significant energy demands and a high level of concentration. Only two previous studies have directly recorded hydration status in competitive sailors. Slater and Tan reported dehydration greater than 2% of body weight in sailors, potentially leading to performance decrements (Slater & Tan, 2007). Lewis et al. reported significant body mass losses in competitive sailors even in cold conditions despite ad libitum fluid intake (Lewis, Fraser, Thomas, & Wells, 2013). The current investigation shows similar results for hydration status when observed separately each day of the competition. What is unique of this study is the progressive dehydration across multiple days of racing. Moreover, the participants of the current study seemed not to be aware of the importance of hydration since they were not able to fully rehydrate following each race. Even though hydration knowledge or awareness was not assessed, it can be hypothesized that their fluid intake was based on thirst. This explanation would align with a previous study conducted by Legg et al. which reported a lack of sport nutrition knowledge in competitive sailors (Legg et al., 1997). Considering the increased physiological stressors involved with sailing as well as the need for elevated mental awareness during competition, hydration should be considered as an important factor in training and competition to ensure optimal performance and safety of the sailors. However, considering the unique nature of competitive sailing, the results of the present study may not be generalizable to other multi-day sporting events. Several studies have found that simple intervention programs could be successful in improving hydration status in various athletic youth (Kavouras et al., 2011; McDermott et al., 2009). This specific population should seriously consider hydration education as part of their preparation (Bergeron, 2015).

The data collected in the current study align with previous studies suggesting young athletes arrive to competition underhydrated (Arnaoutis et al., 2015; Arnaoutis et al., 2013; Da Silva et al., 2012; Yeargin et al., 2010). On day 3 and day 4 of the competition sailors arrived with USG greater than 1.020, a value indicative of suboptimal hydration (Sawka et al., 2007). On day

2 sailors arrived with a mean USG of 1.019, a value close to the aforementioned threshold indicating athletes had little reserve before being classified as hypohydrated. This may have placed athletes at a greater risk of dehydration during the event. McDermott et al. showed similar results in young American football players who arrived to a summer camp with USG values indicative of hypohydration (McDermott et al., 2009). In the same study, educational intervention programs were administered and showed a positive influence on the camper's hydration status. Again, this particular population would most likely benefit from educational interventions (Bergeron, 2015).

A limitation of this study is that the observed loss in body weight may be attributed to gross tissue loss from energy deficit. However, when this measure of hydration status is combined with urine and thirst measures, hypohydration is more accurately identified. Cheuvront and Kenefick (Cheuvront & Kenefick, 2016) do caution the use of body weight loss as a single measure of hydration status across several days. However, the researchers have also proposed a simple approach to assessing hydration state that combines the three measures used in this study. The authors suggest hypohydration is "very likely" with a positive test for all three measures of weight loss, concentrated urine, and thirst (Cheuvront & Kenefick, 2016). Based on this suggestion, it is safe to assume the sailors in this study showed progressive dehydration leading to significant hypohydration throughout the event. Although this study utilizes all three hydration measures, future studies should include dietary logs to determine the exact amount of body weight variation associated with body water loss. Further limitations include the lack of three-day baseline measures for USG and thirst as it was included for body weight. However, USG and thirst ratings were recorded pre-race on the first day of the event and provide a reliable measure of hydration status prior to competition.

The data indicate that young elite sailing athletes dehydrate during competition and concurrently fail to restore euhydration between racing days when drinking ad libitum. This is the first study to show progressive dehydration, particularly as it applies to young athletes. Previous studies have suggested that athletes hydrate most effectively using thirst as a guide (Noakes, 2010), however, these data indicate thirst is not an adequate tool when determining proper fluid intake during and between competitive events. This study supports previous findings (Legg et al., 1997) indicating that competitive sailors lack the needed sports nutrition knowledge to properly rehydrate during days of competition. Considering the significant level of dehydration observed in these athletes, comprehensive intervention programs should be provided to sailors outlining how nutrition, sport science, and particularly hydration can affect physical and cognitive performance during and between competition.

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Authorship

GA, PV, IV, LS, and SK all contributed to data collection. AS and GA were responsible for writing and all authors were involved in the editing process.

Conflicts of Interest

SAK was a scientific consultant for Quest Diagnostics and has active grants with Danone Research. ADS is a scientific consultant for Gatorade Sports Science Institute. No other authors have any conflict of interest to declare.

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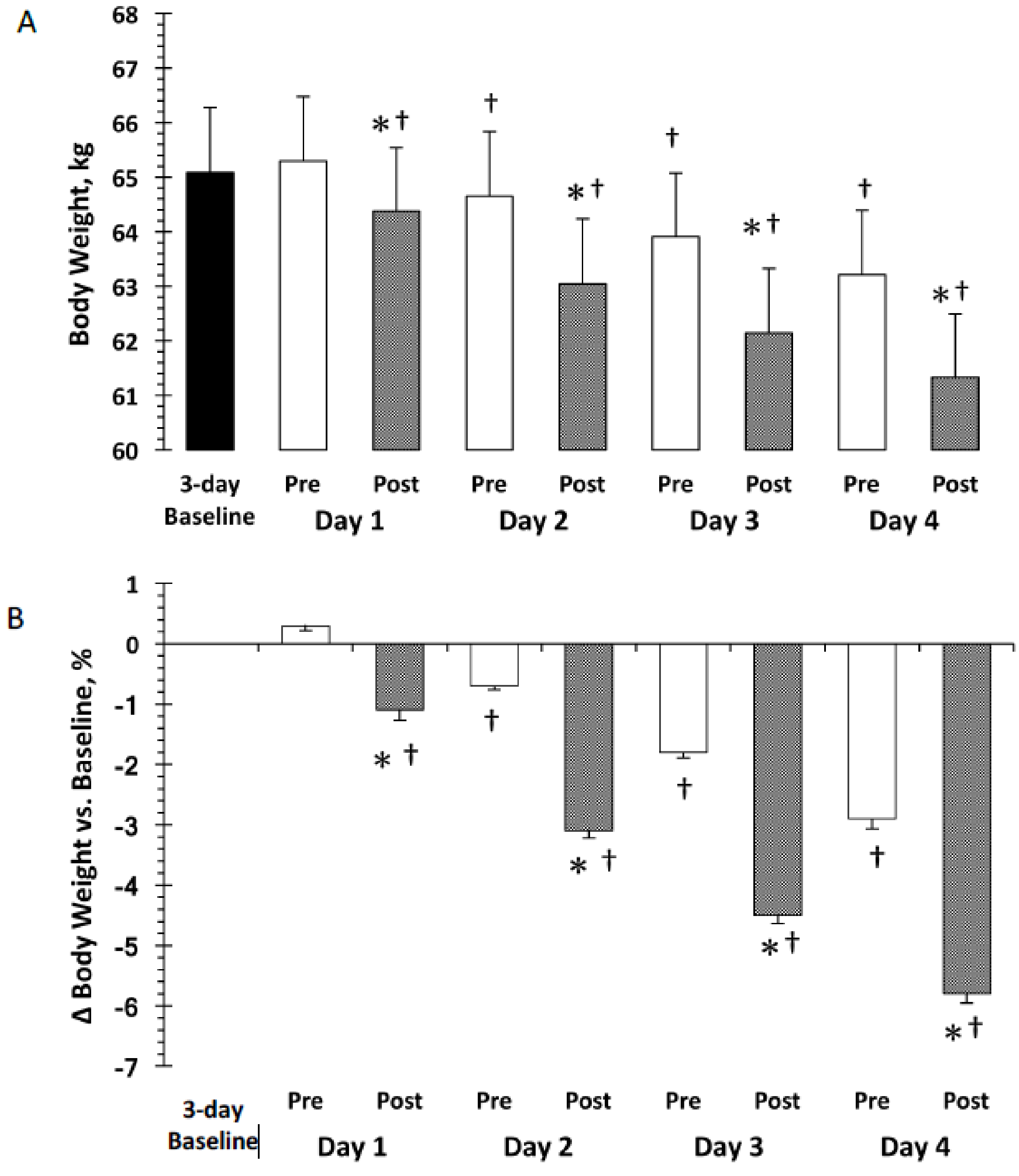

Fig. 1. a: 3-day baseline body weight measurement and pre- and post-race body weight values for day 1 to day 4. **b**: Percent change in body weight as compared to 3-day baseline value.
＊**,** denotes significant change from pre-race value for individual day; † denotes significant different from the 3-day baseline.

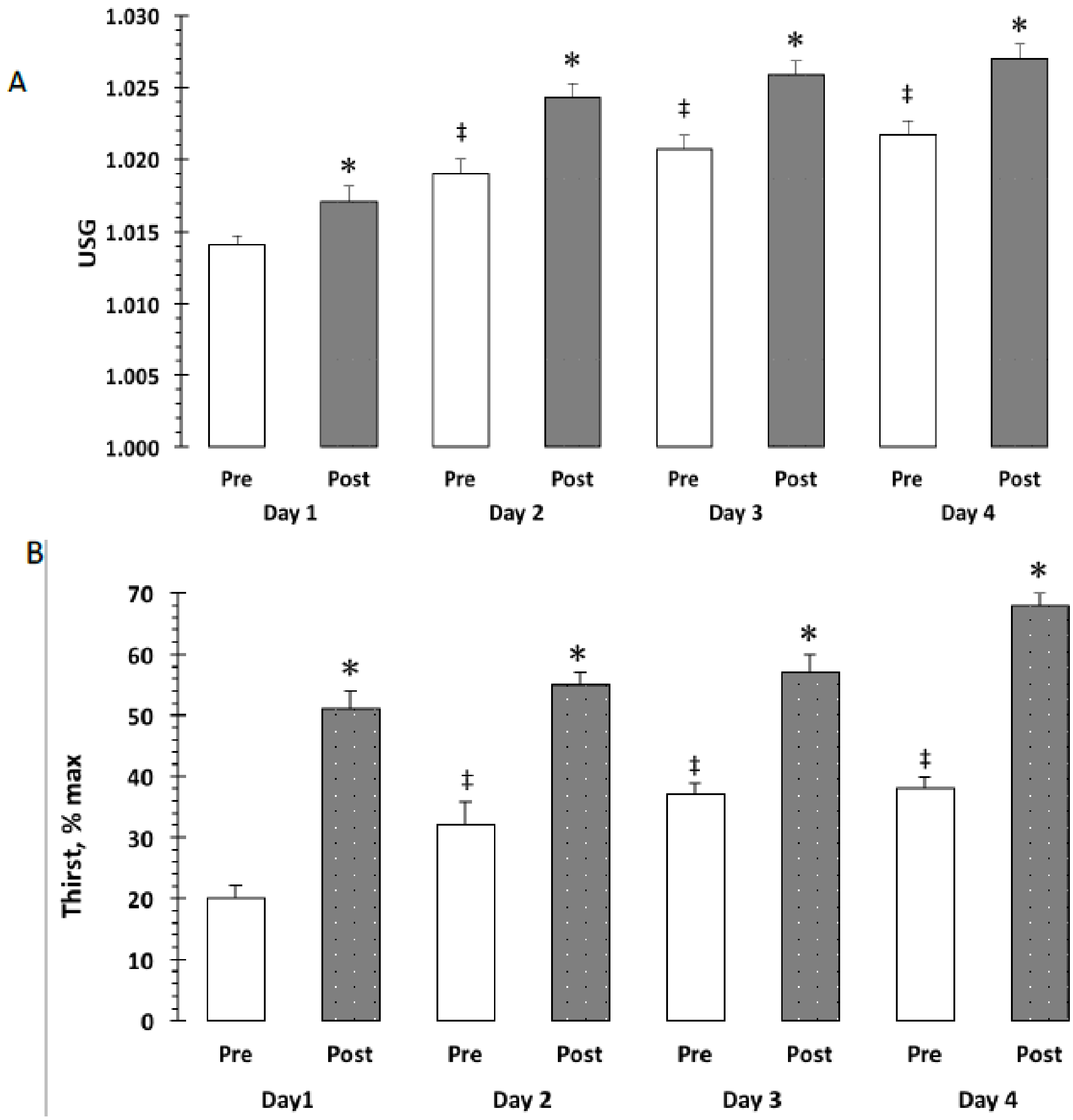

Fig. 2. a: Pre- and post-race USG values. **b**: Pre- and post-race thirst ratings expressed as percent of maximal thirst, based on visual analog scale.

∗, denotes significant change from pre-race value for individual day; ‡, Denotes significant change from day 1 pre-race value.