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ORIGINAL RESEARCH

Hydration Status of Lifesaving Athletes During International Competition

Wade Sinclair and Nick J. Marshall

This study investigated the hydration status of lifesaving athletes in situ during an international competition. Participants were 10 lifesaving athletes (6 male and 4 female) competing in pool- and ocean-based competition across three consecutive days. Assessment included upon-waking urine samples and body mass across 7 days including travel, training and competition days. Urine specific gravity was significantly lower while traveling compared with predeparture ($p < .05$). There were no gender differences for sweat rates, body mass changes, fluids consumed, or percentage dehydration during the training sessions ($p > .05$). Sweat rates were higher than previously reported and there were no significant differences identified for daily body mass changes ($p > .05$). The results of the current study found that lifesaving athletes were capable of maintaining favorable hydration status throughout the course of an international lifesaving event held in hot and humid conditions.

Keywords: swimming; dehydration; body mass changes

International surf lifesaving comprises both ocean and pool-based events with lifesaving athletes at international level undertaking swimming training similar to that of elite competitive swimmers. The pool-based events are timed races consisting of 50, 100, and 200m individual and team relay events held within an Olympic-sized swimming pool. As a summer sport, surf lifesaving is exposed to a variety of environmental conditions that present additional stressors on training and competition, such as ambient environmental and water temperatures, relative humidity, and oceanic conditions. The thermoregulatory demands of swimming are unique due to the forced conductive and convection heat exchange (Nielsen & Davies, 1976) and skin temperatures equilibrating with water temperature upon immersion (Nadel, Holmer, Bergh, Astrand, & Stolwijk 1974). Previously, research has found that swimming in a hot environment may result in an increased heart rate (HR), skin circulation, and esophageal temperature similar to running in the same environment (Holmer & Bergh, 1974), although associated increases in core body temperature (T_C) may be attenuated due to the favorable body-to-water heat transfer (Hue, Antoine-Jonville, & Sara, 2007). Due to the skin being saturated while immersed, however, swimmers experience reduced evaporative potential that may

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provide insufficient stimulus for significant fluid loss (Maughan, Dargavel, Hares, & Shirreffs, 2009). Therefore, it is important to quantify any potential threat to health or performance of lifesaving athletes competing in the warmer summer months.

When exercising in hot and humid environments, it has been well documented that as little as 1–2% dehydration may increase core body temperature (T_C) and cardiovascular strain (Armstrong et al., 1997), while > 2% can decrease aerobic performance, increase physiological strain and lessen impairments in cognitive performances (Casa et al., 2000). Reportedly, sweat rates in male swimmers range between 0.33 and 2.7$L \cdot hr^{-1}$ (Cox, Broad, Riley, & Burke, 2002; Hue et al., 2004; Lemon, Deutsch, & Payne, 1989; Maughan et al., 2009; Macaluso et al., 2011; Soler, Echegaray, & Rivera, 2003) and 0.30 $L \cdot hr^{-1}$ for female swimmers (Cox et al., 2002; Maughan et al., 2009). In addition, previous research has shown sweat rates increase as water temperature (McMurray & Horvath, 1979; Macaluso et al., 2011) or exercise intensity increases (Cox et al., 2002). For example, in elite male water polo players, the demands of competition resulted in sweat rates and fluid intake more than twice that of the training environment (Cox et al., 2002). Further contributing to health concerns is the often inadequate voluntary replacement of fluids lost during prolonged exercise in a hot environment (Armstrong et al., 1997; Greenleaf, 1992). Supporting this is research in to the hydration practices of aquatic athletes during both training (Cox et al., 2002; Hue et al., 2004, 2007; Maughan et al., 2009) and competition (Cox et al., 2002), which confirms that aquatic athletes refrain from consuming fluids ad libitum (Cox et al., 2002).

Although inherent with potential sources of error (for a review, see Maughan, Shirreffs, & Leiper, 2007) employing diurnal BM changes (Casa, Clarkson, & Roberts, 2005; Maughan et al., 2007) or urinary indices such as urine specific gravity (U_{SG}; Armstrong et al., 1998; Popowski et al., 2001) have been suggested as reliable tools for use in the field setting. The American College of Sports Medicine suggests the combined use of BM and U_{SG} appears an effective and reliable methodology for monitoring the hydration status of athletes in the field (Casa et al., 2005; Sawka et al., 2007) where hydration testing during competition, particularly in hot and humid environments, presents an invaluable well-being strategy for athlete management (Oppliger & Bartok, 2002). Therefore, this study sought to describe the hydration status of lifesaving athletes during international competition in a hot and humid environment.

Method

Participants

All athletes (males, $n = 6$, 25.4 ± 1.1 yr; females, $n = 4$, 26.1 ± 1.0 yr) were members of the Australian National Lifesaving team competing in the international lifesaving program at The World Games (TWG) held in Kaohsiung, Chinese Taipei. The World Games are conducted quadrennially under the patronage of the International Olympic Committee, with international lifesaving consisting of ocean events analogous to previously described (Sinclair, Kerr, Spinks, & Leicht, 2009), as well as pool-based competition. At TWG, the competition in the pool consisted of 50, 100, and 200m individual and team relay events held within an indoor Olympic-sized swimming pool with seeded heats conducted in the morning and finals (A and

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B finals) conducted during evening sessions. The top seven national teams from the previous World Lifesaving Championships were invited to compete at TWG along with the host nation to compile an elite eight nation competition. The TWG program incorporated three consecutive days consisting of two days of pool-based competition: day one (PC1) and day two (PC2), followed by the concluding day of ocean-based competition (OC).

Procedure

Participants were assembled for an overnight predeparture camp before leaving Australia, during which time athletes were advised of experimental protocols. All athletes were advised of potential experimental risks and then voluntarily provided written informed consent to undertake this research in accordance with the Institutional Human Research Ethics subcommittee. Assessment of upon-waking BM and urine samples from the first void of the morning commenced on the morning of the predeparture camp and concluded on the morning of the final day of competition (OC).

Participants were requested to provide a midstream urine sample from the first urination of each morning before any fluids or food being consumed, which was assessed for U_{SG} via a handheld refractometer (Atago URICON-NE; Atago Co. Ltd., Tokyo, Japan) and which quantifies the density of the urine compared with that of water via refractometry (Oppliger & Bartok, 2002). U_{SG} is noninvasive, effective and reliable in detecting dehydration in athletic environments (Armstrong et al., 1994; Oppliger & Bartok, 2002). In addition, the first urination of the morning was employed to avoid any influence of the acute consumption of fluids to enhance the reliability of the samples (Armstrong et al., 1994; Oppliger & Bartok, 2002; Popowski et al., 2001). Recently, a morning U_{SG} of 1.026 $g{\cdot}mL^{-1}$ has been proposed as the upper limit for euhydrated men with morning urine samples shown to be more concentrated than 24 hr urine collections (Armstrong et al., 2010). In the current study, morning samples were deemed more appropriate, and a U_{SG} of 1.020 $g{\cdot}mL^{-1}$ was used to represent the upper limit of euhydration in consideration of the anticipated sweat losses while traveling and based on recommendations reflecting an elite-athlete focus (Casa et al., 2000; Popowski et al., 2001).

Upon-waking BM was recorded to the nearest 0.1 kg (Tanita TBF-521, Tanita Corporation, Tokyo, Japan) after voiding and while wearing minimal clothing with athletes requested to wear the same clothing for each morning BM assessment. Nude BM was not employed due to inappropriate facilities available for data collection and time restraints. The coefficient of variation (CV) and daily percentage body mass (%BM) fluctuations as well as daily U_{SG} changes were calculated via previously published formulae (Lew, Slater, Nair, & Miller, 2010).

To assess BM changes during training sessions, participants were weighed in only their swimming costumes before the session as well as immediately following the session once participants had toweled themselves dry as much as possible. In addition, water bottles were weighed to the nearest 1g (Siena, Soehnle, Germany) before and following each training session to approximate fluid consumption with participants consuming fluids ad libitum. As a limitation of this evaluation, excess fluids inadvertently consumed via swallowing pool water, although likely to elicit error in sweat rate determination (Cox et al., 2002), were not accounted for in the calculations. Individual sweat loss and percentage change in fluid balance (% dehydration) that occurred during the 1.5 hr training sessions held on T1 and T2 were calculated as per previously published formulae (Cox et al., 2002). Each training session consisted of 1.6 km warm up followed by 1–1.5 km of variable speed work and finished with 30 min pool event specific skills.

Environmental conditions were assessed via a handheld weather meter (Kestrel 4000, Nielsen-Kellerman, Boothwyn, USA) while inside the competition venue during both training and competition. The environmental conditions during the predeparture camp training sessions were 11.9 ± 2.3 °C (dry bulb temperature) and 60.6 ± 8.5% relative humidity. While in Chinese Taipei, all training and pool competitions were held in an indoor pool where the average environmental conditions across the four days were 29.2 ± 2.0 °C (dry bulb temperature), 26.5 ± 2.6 °C (wet bulb temperature), and 80.3 ± 9.1% relative humidity with an average water temperature of 27.1 ± 0.3 °C ($p > .05$). OC environmental conditions were 28.3 ± 3.3 °C (dry bulb temperature) and 83.6 ± 6.6% relative humidity.

Statistical Analysis

All variables were normally distributed as determined via the Kolmogorov-Smirnov test of normality. A repeated measures one-way analysis of variance (ANOVA) was used to assess differences in U_{SG} and BM between days. Following statistical power analysis, a minimum sample size of 9 (BM) and 10 (U_{SG}) was determined sufficient for statistical power of 0.8 with alpha set at 0.05 (Thomas, Nelson, & Silverman, 2011) based on previous research (Hue et al., 2004; Silva et al., 2010). Differences between training sessions were assessed via paired-samples T-test with secondary analysis between genders completed using the nonparametric Kruskal-Wallis ANOVA. The alpha for all analyses was set at 0.05, and all variables are presented as mean ± *SD*.

Results

There was a main effect of time for U_{SG} with all assessments conducted while traveling lower than that recorded on the morning of the predeparture camp (Figure 1; $p < .001$).

During the training and competition days, there were no differences identified for daily morning BM or %BM change ($p > .05$) with a %CV for daily BM assessments of 0.53 ± 0.26% for male and 0.38 ± 0.9% for female participants ($p > .05$).

There were no significant differences between the training sessions held on T1 and T2 for any of the assessed variables pre- or posttraining session ($p > .05$). The only gender difference between training sessions was the significantly heavier pre- and posttraining session BM of the males compared with that of the females (Table 1; $p < .05$).

Discussion

International lifesaving athletes undertake swim training sessions similar to that of elite-level swimmers often training within the same swimming squads. Although previous research with swimmers may therefore be comparable, no research to date has investigated the hydration status of lifesaving athletes during competition

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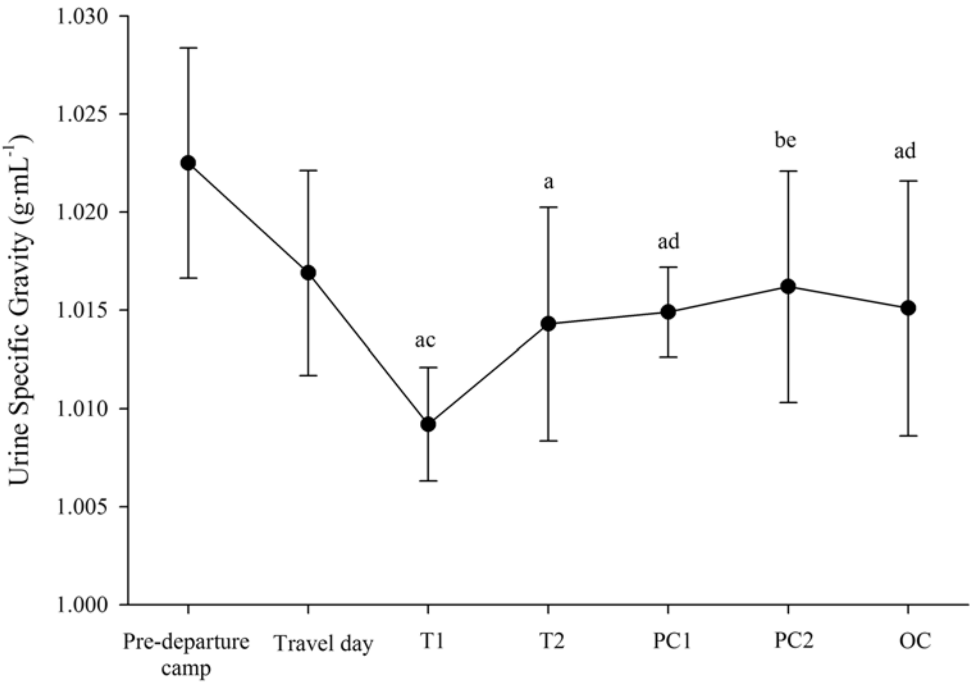

Figure 1 — Mean (± *SD*) Urine Specific Gravity (U_{SG}) for participants on the morning of the predeparture, travel, training (T1 and T2) and pool (PC1, PC2) and ocean (OC) competition days. [a] $p < .01$ lower than predeparture; [b] $p < .05$ lower than predeparture; [c] $p < .01$ lower than travel day; [d] $p < .05$ greater than T1; [e] $p < .01$ greater than T1.

Table 1 Mean (± *SD*) Gender Body Mass Characteristics and Fluid Exchanges During Training Sessions Held on the Training Days (T1 and T2)

	Male	Female
Sample size	6	4
Pretraining body mass (kg)	83.0 ± 6.1 *	71.3 ± 3.5
Posttraining body mass (kg)	82.6 ± 6.8 *	71.2 ± 3.3
Absolute change in body mass (kg)	-0.39 ± 0.39	-0.12 ± 0.49
Fluids consumed (mL)	725 ± 443	714 ± 675
Sweat loss (mL)	1117 ± 411	830 ± 283
Sweat rate ($L \cdot hr^{-1}$)	0.74 ± 0.27	0.55 ± 0.19
% dehydration	0.49 ± 0.47	0.15 ± 0.70

* P < 0.05, males significantly greater than females

or training. The results of the current study contribute to this lack of information relating to the hydration status of lifesaving athletes, specifically during international competition in a hot and humid environment. Interestingly, the current study identified higher sweat rates during training than previously reported for other male aquatic athletes (0.29–0.48 $L \cdot hr^{-1}$; Cox et al., 2002; Lemon et al., 1989; Maughan et al., 2009) and for elite female swimmers (0.30 $L \cdot hr^{-1}$; Cox et al., 2002; Maughan et al., 2009). Similarly, absolute BM changes by participants during the 1.5 hr training sessions in the current study exceeded that previously reported in elite-level swimmers (Maughan et al., 2009).

Previous research utilizing the same water temperature to that in the current study (~27 °C) have identified lower sweat rates than those in the current study during training for elite male water polo players (0.29 $L \cdot hr^{-1}$; Cox et al., 2002) and adolescent interscholastic swimmers (0.48 $L \cdot hr^{-1}$; Lemon et al., 1989). Similarly, the results for the female participants in the current study were higher than those reported for elite-level female swimmers (0.31 $L \cdot hr^{-1}$; Cox et al., 2002; Maughan et al., 2009). Differences between swimmers and the lifesaving athletes may be explained by their respective training regimes. Although both undertook similar swim sessions, participants in the current study were multidisciplinary compared with the elite-level swimmers, so it would be fair to assume that the swimmers were completing near exclusive swimming training, while the participants in the current study also included running, surf ski, and Malibu surfboard paddling (Sinclair et al., 2009). Swimmers, courtesy of their near-exclusive aquatic training, are less acclimatized than land-based athletes for a given thermal load (Henane, Flandrois, & Charbonnier, 1977), thermoregulating better in cooler water (20 °C) than land-based athletes, although the converse applies for land based exercise (McMurray & Horvath, 1979). Therefore, the higher sweating response, indicative of a heightened thermoregulatory response, in the participants of the current study, may be the result of their multidisciplinary training.

In addition, ambient environmental temperatures may play a significant role on T_C regulation during aqueous exercise (Macaluso et al., 2011; Soler et al., 2003). Therefore, the higher sweat rates may also be partially attributable to the participants still becoming accustomed to the altered climatic conditions (Hue et al., 2004). Participants departed Australia amid cooler conditions than those experienced in Chinese Taipei. Adaptation to hot and humid environments, such as that experienced during the current study, typically occurs within 7–10 days (Pandolf, 1998; Wendt, van Loon, & van Marken Lichtenbelt, 2007) of exposure. However, much physiological adaptation occurs after 3–6 days with increased sweat rates often observed after 7–14 days (Wendt et al., 2007). Previously, a significant increase was observed in the sweat rate of elite triathletes after just 2 days in a tropical climate, suggesting a beneficial sweating response albeit as accessed via an outdoor running protocol (Hue et al., 2004). Consequently, the triathletes experienced a concomitant performance decrement as well as higher heart rate, BM changes, and T_C during recovery, which the authors suggested was a result of the level of dehydration (Hue et al., 2004).

The U_{SG} recorded on the predeparture camp morning was similar that recorded during previous lead up camps (1.024 ± 0.005 $g \cdot mL^{-1}$) and within the revised euhydration limits of 1.026 $g \cdot mL^{-1}$ (Armstrong et al., 2010) but outside limits employed for the current study. However, the lower U_{SG} reported while overseas compared

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with the predeparture camp as well as minimal fluctuations in BM despite relatively large sweat rates suggest participants were capable of adequately maintaining hydration in situ throughout their time overseas. This finding may be the result of participants being informed of their daily U_{SG} and BM results throughout the travel period. Future research should look to identify the impact of specific feedback in relation to hydration indices in situ on elite-athletes.

During competition, participants recorded higher U_{SG} compared with the first training day (T1), albeit still under the proposed classification for being euhydrated (Casa et al., 2000; Popowski et al., 2001). Acute increases in fluid consumption are known to reduce U_{SG} (Armstrong et al., 1994) and while en route to TWG from Australia, participants in the current study were continually drinking while in transit, which potentially explains the lowest U_{SG} reading on the subsequent morning (T1). As the days and the exposure to the hot and humid conditions progressed, however, participants U_{SG} increased progressively although predeparture levels were not attained. These results suggest the need for hydration status to be monitored throughout competition as athletes focus their attention to the competitive demands of their sport.

Inherent limitations of the current study included the number of participants, focus on pool-based competition, and additional support team members for the team used in the study. Based on previous research, however, a sample size of 10 participants was determined sufficient to identify daily variations in BM and U_{SG} while teams contesting international lifesaving events are limited in number (10–12 athletes). The current study was also restricted to one team, as collaboration between nations at TWG was not possible due to the competitive environment of the games. In addition, pool-based competition was the primary focus for the current study given indoor competition venues are often used for international pool lifesaving competitions, often resulting in high relative humidity and ambient temperatures. Furthermore, logistics associated with the team used for the current study prevented results from the ocean-based competition at TWG being included, and future research should explore the impact of the outdoor environment on ocean-based lifesaving competition. Finally, it is acknowledged that while many international lifesaving teams may not have the additional support personnel to undertake hydration assessments, the results of this study are aimed at increasing awareness of the influence that 2 days of indoor pool-based international lifesaving competition may have on the hydration status of lifesaving athletes.

Coaches and team management should employ suitable hydration monitoring where possible when teams are exposed to hot and humid environments to minimize any potential impairment of athletic performance. Although actively swimming may provide insufficient stimulus to promote body water losses, other variables such as exercise intensity, water temperature, and ambient environmental conditions also contribute to an athlete's susceptibility. Sweat rates for participants in the current study were greater than those previously reported in the training environment for other aquatic athletes such as swimming and water polo. The use of specific feedback of an individual's hydration indices, such as U_{SG} and daily BM changes, may aide lifesaving athletes to maintain adequate hydration during international competition. In the current study, participants were capable of successfully maintaining their favorable hydration status and minimizing daily BM fluctuations during training and competition at an international competition conducted in a hot and humid environment.

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