

8-15-2019

## Measures of Fluid Loss during Surfing: A Preliminary Analysis in Recreational Surfers

Rudi A. Meir

*Southern Cross University, rudi.meir@scu.edu.au*

Zachary James Crowley-McHattan Dr

*Southern Cross University, zac.crowley@scu.edu.au*

Lyndon O. Brooks

*Southern Cross University, lyndon.brooks@scu.edu.au*

Blake Duncan

*Southern Cross University, blaked@broncos.com.au*

Christian Gorrie

*Southern Cross University, christiangorrie@gmail.com*

Follow this and additional works at: <https://scholarworks.bgsu.edu/ijare>

See next page for additional authors



Part of the [Exercise Physiology Commons](#), [Exercise Science Commons](#), [Health and Physical Education Commons](#), [Leisure Studies Commons](#), [Outdoor Education Commons](#), [Sports Sciences Commons](#), [Sports Studies Commons](#), and the [Tourism and Travel Commons](#)

---

### Recommended Citation

Meir, Rudi A.; Crowley-McHattan, Zachary James Dr; Brooks, Lyndon O.; Duncan, Blake; Gorrie, Christian; and Sheppard, Jeremy (2019) "Measures of Fluid Loss during Surfing: A Preliminary Analysis in Recreational Surfers," *International Journal of Aquatic Research and Education*: Vol. 12: No. 1, Article 10. DOI: <https://doi.org/10.25035/ijare.12.01.10>

Available at: <https://scholarworks.bgsu.edu/ijare/vol12/iss1/10>

This Research Article is brought to you for free and open access by the Journals at ScholarWorks@BGSU. It has been accepted for inclusion in International Journal of Aquatic Research and Education by an authorized editor of ScholarWorks@BGSU.

---

# Measures of Fluid Loss during Surfing: A Preliminary Analysis in Recreational Surfers

## Authors

Rudi A. Meir, Zachary James Crowley-McHattan Dr, Lyndon O. Brooks, Blake Duncan, Christian Gorrie, and Jeremy Sheppard

### Abstract

Surfing is a popular sport, but little is known about the extent to which recreational surfers experience fluid loss from this activity. The principal objective of this research was to estimate fluid loss during a surfing session through changes in pre- to post-session urine color (Ucol), urine osmolality (Uosm), and body mass (BM). Data were collected from 11 recreational surfers across 14 surf sessions conducted under various environmental (mean water temperature = 22.1  $SD \pm 2.3$ ; range = 20-26°C; air temperature range = 13.1-31.5°C; relative humidity range = 37.5-88.1%) and surfing conditions (e.g. winter/summer, wave type, location, environmental and water conditions). Linear mixed effects models indicated that participants experienced significant pre- to post-session changes in BM ( $p \leq 0.001$ ), but not in Ucol or Uosm. These findings suggested that recreational surfers may experience fluid loss (measured by pre- to post-surfing BM) that may impact on their performance and health, and therefore they should adopt a hydration strategy to minimize this impact.

*Keywords:* hydration, recreational surfing, fluid loss

### Introduction

Surfboard riding (surfing) continues to increase in popularity around the world. As a sport it is synonymous with an outdoor lifestyle and the beach culture. Millions participate in the sport worldwide with more than 2.7 million in Australia alone (Climstein, Pollard, Furness, Walsh & McLellan, 2015). At the highest skill level a professional World Tour is run by the World Surf League (WSL) for both males and females. In addition, the International Surfing Association (ISA) holds annual world championships for males and females at Junior, Senior, and Masters levels. In 2015 the ISA also held the inaugural World Adaptive Surfing Championship which is now an annual event.

Despite its popularity, research into the physiological demands of the sport has been limited (Mendez-Villanueva & Bishop, 2005). Notwithstanding, research has shown that even at the recreational level surfing can involve participants spending on average 2 hours in the water with some participants spending considerably longer when the environmental conditions allow (Meir, Zhou, Rolfe, Gilleard & Coutts, 2012). Recreational surfers have been shown to spend a significant proportion of their time paddling (~50%) or stationary (~40%) and the least amount of time actually catching and riding waves (~4-8%) (Mendez-Villanueva & Bishop, 2005; Barlow, Gresty, Findlay, Cooke & Davidson, 2014; Meir, Lowdon & Davie, 1991). Previous research reported that the average heart rate while surfing varied between 135-146 ( $SD \pm 6-16.8$ )  $b \cdot min^{-1}$  for recreational surfers (Barlow et al., 2014; Meir et al., 1991) and 139-146 ( $SD \pm 11-20.0$ )  $b \cdot min^{-1}$  for competitive surfers (Farley, Harris & Kilding, 2012).

Surfing is both a sport and recreational activity involving intermittent bouts of physical effort of varying intensity and duration (Mendez-Villanueva & Bishop, 2005; Meir et al., 1991). As with other forms of physical activity, the physical demands of surfing could potentially lead to significant fluid loss from sweating (Harvey, Meir, Brooks & Holloway, 2008; Prado, da Silva Barroso, Góis & Reinert, 2009). Notwithstanding this, surfing is undertaken in a fluid environment, and so visual indicators of sweating (e.g., sweat beading on the surface of the skin) are not necessarily evident. Having no visual indication of fluid loss can give surfers the impression that they are not experiencing any significant fluid loss as a result of their physical effort. In a recent report to Surfing Australia, evidence from the responses of 685 Australian surfers established that approximately 25% “never” drank additional fluids before surfing (Meir et al., 2012). Given that surfers can spend from 1-3 hours in the water, this finding is cause for concern.

Fluid loss is commonly experienced during physical activity and the extent to which it occurs can vary amongst individuals (Kenefick & Cheuvront, 2012). The research evidence shows that a loss of 2% body mass (BM) is the threshold at which aerobic performance becomes impaired (Eijssvogels, Scholten, Duijnhoven, Thijssen & Hopman, 2013; Maughan & Shirreffs, 2010a; Sawka et al., 2007). Because water is critical to cardiovascular function, any reduction in body water will result in increased cardiovascular and thermoregulatory stress during exercise (Hargreaves, 2008; Maughan & Shirreffs, 2010b). Hence, fluid loss should be carefully monitored during exercise and physical activity.

Heat tends to pass from locations of high temperature (e.g., the core) to locations of lower temperature (e.g., the skin). The body has four mechanisms of heat transfer: (i) conduction, (ii) convection, (iii) radiation, and (iv) evaporation. Combined, all four mechanisms allow the body to maintain thermal balance by losing body heat to the environment (McArdle, Katch & Katch, 2010). Water immersion, as with swimming, sees heat loss primarily via convection, which is the transfer of heat from one place to another between a surface and a fluid (e.g., liquid or gas) (Kerlake 1972; McMurray & Horvath, 1979; Silverthorn 2010). More typically, thermoregulation during physical activity (e.g., land-based) is achieved most efficiently through sweating in the presence of convection from air movement (Falk, 1998). Since surfing takes place in the ocean one would expect the effectiveness of this mechanism to be reduced. This appears to be confirmed by research showing that sweat rates among water polo players and swimmers, when compared to land-based forms of training, are lower (Cox, Broad, Riley & Burke, 2002; Henkin, Sehl & Meyer, 2010). This appears to be a product of adaptations related specifically to the ambient conditions (i.e., air temperature and relative humidity) in the training environment (Henkin et al., 2010).

Exercise induces a rise in metabolic heat production, especially when combined with high ambient temperatures and reduced capacity for heat loss, which leads to increased body temperature (Maughan & Shirreffs, 2010b). An increase in body temperature is often associated with dehydration from sweat loss, which is largely responsible for performance decline in hot and humid environments (Casa, Clarkson & Roberts, 2005). As a result, many sport programs employ strategies such as measuring pre- and post-exercise BM changes, changes in urine color (Ucol), and changes in urine osmolality (Uosm) or urine specific gravity (Usg) to estimate changes in fluid status of athletes (Armstrong, 2005; Harvey et al., 2007; Meir, Zhou, Gilleard & Coutts, 2011).

Recording body mass (BM) changes pre- and post-activity, in order to determine fluid loss, is seen as a general indicator of the amount of sweat lost as a result of physical activity (e.g. Armstrong, 2005; O'Hara et al., 2010; Meir, Brooks & Rogerson, 2011). This is a commonly used method of monitoring hydration status, particularly when dehydration occurs (with or without exercise) over a period of 1 to 4 hours (Armstrong, 2005). What is not clear is whether BM changes are likely to be observed with surfing, particularly given the physically-demanding nature of the sport. Further, the issue of fluid loss may be exacerbated when surfing, given that fluid losses are reported to be greater following saltwater immersion compared to fresh water (Carrasco, 2008; McMurray & Horvath, 1979). Carrasco (2008) has also suggested that wearing a wetsuit, to minimise the hypothermic effects of cooler water temperatures in the winter months, is likely to exacerbate the increase in metabolic heat production that occurs during exercise. Intuitively, this could lead to greater sweat rates, increasing the amount of fluid lost while surfing, and perhaps producing a lower post-surf BM. To further complicate this issue, many surfers in warmer geographical locations are likely to wear sunscreen to protect them from the sun, which may also reduce the effectiveness of their sweat response. Nevertheless, research has shown in Australia that approximately 20% of surfers did not use sunscreen on any exposed parts of the skin in the warmer months with this number increasing to almost 50% in the cooler months (Meir, Zhou, Rolfe, Gilleard & Coutts, 2015).

Urine color (Ucol) is often used to indicate general fluid hydration status because it is simple to collect and easy to assess in a field setting (Armstrong et al., 1994). The body's fluid levels determine the amount of urine produced, while volume of fluid produced primarily determines Ucol, with a pale urine color being indicative of a euhydrated athlete (Casa et al., 2005). A higher volume of urine results in a diluted concentration of metabolic solutes excreted from the kidneys, contrasting to higher concentrations of solutes present when lower volumes of urine are excreted (Maughan & Shirreffs, 2010a). During exercise the body attempts to minimise fluid loss resulting in a darker Ucol, thus indicating a greater level of dehydration (Kenefick & Chevront, 2012; Ftaiti, Grélot, Coudreuse & Nicol, 2001). Ucol can also be affected by factors such as

recent food and medications consumed, illness, and ingestion of large volumes of hypotonic fluid which may reduce its reliability (Harvey et al., 2008). Although Ucol lacks the precision and accuracy of Uosm, Armstrong (2005) has indicated that it might be considered effective in scenarios that do not require high precision (e.g., athletic and industrial settings). In addition, Driskell and Wolinsky (2011, p.365) suggested that Ucol is one of the preferred methods of assessing hydration status in a field setting.

Uosm measures the concentration (number) of solutes (particles) per weight (kilogram) of fluid, while Usg measures the density (mass per volume) of a sample compared with pure water (Armstrong, 2005). Uosm is closely correlated ( $r^2 = 0.96$ ) with Usg, demonstrating a strong linear relationship (Armstrong, 2005; Armstrong et al., 1998). Urinary indices, such as Uosm and Usg, are viewed as more accurate measurements of dehydration, as they are able to detect more subtle variances in urine samples than Ucol measurements alone. Specifically, Uosm has been reported to be a useful indicator of hydration status in athletes training or competing in warm environments (Shirreffs & Maughan, 1998). By contrast, others have found Uosm to be a poor indicator of changes in hydration status when used up to six hours post-exercise (Kovacs, Senden & Brouns, 1999).

Ultimately, there is little agreement regarding the best single method for assessing hydration status in an athletic setting. Practically one should use a method that has convenience for the given sporting context and that does not require expensive equipment or high levels of technical expertise. To this end, this study observed pre- to post-surf changes in BM, Ucol, and Uosm to determine the extent of fluid loss experienced among recreational surfers during a typical surf session. Data were collected under a variety of surfing conditions with participants wearing what would be considered typical surf wear for the surfing session being observed. This was deemed appropriate in order to provide “indicative” (ecologically appropriate) measures of fluid status among recreational surfers (Cox et al., 2002).

## Method

### Participants

We employed a convenience sample of eleven males (mean age =  $23.0 \pm SD 2.8$  years) who self-identified as recreational surfers as participants in this study. Participants took part in a total of 14 surf sessions. Three participants took part in two surf sessions (session total = 6), while the remaining eight participated in one session only (session total = 8). Participation was influenced by availability and surf session suitability (i.e., under normal circumstances the participant would have considered the surf good enough to go out in). All participants were short board riders (board length under 6' 4" or 1.93cm) with a minimum of 4 years recreational surfing experience. Participants were required to be free from any musculoskeletal injuries or conditions that may

affect their performance (e.g., illness). Institutional ethics approval was provided (approval number ECN-12-305) with informed consent gained from each participant prior to participation.

### **Procedures**

All 14 surfing sessions were conducted on beaches in northern New South Wales, Australia, with a variety of different surfing conditions experienced across different days and at different times of the year. This was done in order to ensure that this initial observational analysis was conducted in a variety of conditions typically experienced by recreational surfers. As a result, participants self-selected surf wear considered appropriate to the time of year that they were observed (e.g., t-shirt and board shorts in warmer conditions or wetsuit (steamer-length) in cooler conditions). Measures of BM, Ucol, and Uosm were collected immediately prior to and after each surf session. All participants were required, if necessary, to empty their bladder and bowel prior to any data collection. They were also asked to abstain from consuming alcohol and caffeine-based beverages in the 4 hours prior to surfing. They also were instructed to abstain from eating a meal in the 2 hours immediately prior to surfing and not to undertake heavy total body exercise in the 24 hours prior to surfing. Any fluid consumption and urine excretion between initial and final data collection were measured and recorded. All participants were asked to avoid emptying their bladder while in the surf. Environmental measurements (i.e., ambient temperature, relative humidity, water temperature, wind direction) were recorded for each session. Participants were given no instruction other than to surf as they normally would, subject to the prevailing conditions. Each surf session was recorded with a HD video camera for time-motion analysis purposes.

**Body Mass.** Body mass (BM) was recorded pre- and post-surfing episode using a set of Charder MS3200 portable medical scales (Charder Electronic Co, Ltd. Taichung City, Taiwan) which measured BM to the nearest 0.1kg. The scales were placed on a level concrete pad or other flat surface for all measurements. Participants were weighed in underwear only for both measurements and were towel-dried prior to being weighed post-surfing.

**Urine Color.** Urine color (Ucol) was determined pre- and post-surfing episode by comparing the collected urine sample directly against the NCAA's Assess Your Hydration Status urine color chart (Armstrong et al., 1994). The chart uses an 8-point scale with a score between 1 (very light yellow/clear color) and 8 (dark yellow/brown color) representing hydration status. Two researchers independently assessed pre- and post-surf Ucol against the color chart, and when agreement on the color was achieved its value was recorded for later analysis.

**Urine Osmolality.** Urine osmolality (Uosm) (mOsmol/kgH<sub>2</sub>O) was determined from the same sample used in the Ucol assessment. An Osmocheck digital refractometer (Vitech Scientific Ltd., UK) was calibrated using bottled water to give a neutral reading prior to the transfer from the collection container to the refractometer's prism surface using a pipette calibrated to 200 $\mu$ L. The same sample of bottled water was used for each trial. The refractive index of the urine sample is measured by the refractometer which calculates and displays Uosm in mOsmol/kg of H<sub>2</sub>O. The American College of Sports Medicine (ACSM) position stand (Casa et al., 2005) suggests that a Uosm  $\leq$  700 mOsmol/kgH<sub>2</sub>O is indicative of euhydration (i.e., normal state of body water content or the absence of absolute or relative hydration or dehydration).

**Environmental Conditions.** Surf conditions (i.e., wave size and wind direction) and water temperature were recorded for each session using the daily surf report accessed from CoastalWatch.com. Ambient temperature and relative humidity values were measured using a Testo 608-H1 hygrometer (Testo Limited, UK) pre- and post-surfing episode. The hygrometer was left on the beach, out of direct sunlight, for the duration of the session to ensure the measurement was as accurate as possible.

**Time-Motion Analysis.** Each surf session was recorded using a Panasonic NV-GS150 tripod mounted video camera. The recording was transferred to a digital format and analyzed in order to determine how long each subject spent performing each of the five activities considered for the study (i.e., paddling, stationary floating, paddling for a wave, riding a wave, and miscellaneous activity). This was determined by pausing the video playback and recording the start/finish time each time the participant changed from one activity to another.

### **Statistical Analysis**

The data (BM, Ucol, & Uosm) were assessed using IBM SPSS Statistics software (v22.0) to calculate the descriptive statistics of mean, standard deviation, and value ranges. The principal objective of the descriptive analysis was to estimate the mass of fluid lost during a surfing session. This was measured as pre- to post-session mass loss (dependent variable mass in kg, effect = Pre-post). Four variables that may influence the mass of fluid lost were assessed: the ambient air temperature (ATemp in degrees C), water time (WTime in minutes), relative humidity (RHumid in percent), and whether the surfing session occurred wearing board shorts and t-shirt or while wearing a wetsuit (referred to collectively hereafter as "Condition").

Non-independence is present in the data analyzed here because there were three participants who contributed data in both the warmer and cooler conditions. To deal with this, a linear mixed effects model (Pinheiro & Bates, 2009) was fitted to the BM data with a between-subjects random effect in

addition to the within-subjects residual. Readers are referred to the UCLA Statistical Consulting Group web page, Introduction to Linear Mixed Models (<https://stats.idre.ucla.edu/other/mult-pkg/introduction-to-linear-mixed-models/>), which clearly describes how linear mixed effects models ‘are particularly used when there is non-independence in the data.’ This web page also lists a number of references to the model including the Pinheiro and Bates (2009) book referenced here.

All available data were used in the model with the data not collected on some (i.e., those who surfed only once in either the warmer or cooler condition) treated as missing at random (MCAR or MAR) (Dong & Peng, 2013). Restricted maximum likelihood (REML) estimates were obtained and it was assumed that the estimates obtained were consistent and asymptotically efficient despite the missing data (Dong & Peng, 2013). Note that no attempt was made to estimate missing data since the maximum likelihood method used produces accurate estimates and standard errors in the presence of what might be seen as missing data: i.e., the data structure might be conceived of as incomplete in respect of a design in which all participants were intended to participate in both the warmer and cooler conditions.

Pre-post was coded as a dummy variable with pre = 0 and post = 1. Similarly, board shorts or wetsuit was coded as a dummy variable with board shorts = 0 and wetsuit = 1. The potential covariates were centered near their means prior to analysis with ATemp = ambient temperature = 22, WTime = water time – 75, and RHumid = relative humidity – 64. The continuous variables were centered this way so that the parameter estimates applied to an ambient temperature of 22 degrees C, a water time of 75 minutes and a relative humidity of 64 percent.

An initial model was fitted to the BM data with the predictors ATemp, RHumid, WTime, Condition and Prepost as main effects, and the interaction effects for ATemp by Prepost, RHumid by Prepost WTime by Prepost, and Condition by Prepost. The model was systematically reduced by eliminating non-significant ( $p > 0.05$ ) interaction effects one at a time in descending order of their p-value sizes. Non-significant ( $p > 0.05$ ) main effects were then eliminated one at a time in descending order of their p-value sizes, subject to the constraint that main effects for variables involved in retained (significant) interaction effects were retained. Results are interpreted based on the parameter estimates for the effects retained (significant interaction and main effects, and main effects for variables involved in significant interaction effects) in the final model. The same set of potential predictors, and the same modelling approach, was employed for the analyses of Ucol and Uosm.

## Results

### Descriptive Statistics

Table 1 presents the mean (*SD*) values for each of the recorded variables across all 14 surf sessions. When combined, the mean water temperature across all sessions was = 22.1 (*SD* ± 2.3), with a range of 20-26°C. Mean ambient temperature was 22.3°C (*SD* ± 4.7), with a range of 13.1-31.5°C. Mean relative (%) humidity was 64.2% (*SD* ± 13.3), with a range of 37.5-88.1%.

### Time-Motion Analysis

Table 2 shows the amount of time spent in each of the five activities measured across all 14 surf sessions. The data reveals paddling was the most common activity (~52% of total time in water) across all sessions. Participants were stationary for ~31% of the time and spent ~10% of the time doing miscellaneous activities (e.g. retrieving their board, wading through water). Paddling for and riding waves each accounted for ~3% of the total time in the water.

### Body Mass

All two-way interaction effects were eliminated except for ATemp by Prepost. This indicates that BM change pre- to post-session did not depend significantly on relative humidity, water time or condition (i.e. warmer or cooler). The interaction effect involving condition (e.g. board shorts) was eliminated first (least significant), that involving relative humidity second, and that involving time spent surfing (water time) last. It is worth noting that, at the time it was eliminated, the coefficient for water time was negative, indicating increasing mass loss with longer water times, with this variable having a p-value of  $p = 0.181$ . The main effect for RHumid was then eliminated to yield the final model.

The parameter estimates for the fixed effects with standard errors, tests of significance and 95% confidence intervals for the final model, are reported in Table 3. The estimate for the Pre-post effect indicates a mean loss of 2.54 kg of body mass pre- to post-session at an ambient temperature of 22°C. The estimate for the ATemp by Pre-post effect indicates an average loss of 0.18 kg BM (pre- to post-session) with each one degree increase in ambient temperature above 22°C.

**Table 1.** Mean ( $\pm$  *SD*) changes in pre- to post-surf body mass, urine color and urine osmolality (N = 11)

Condition	<b>Board shorts only (sessions = 7)</b>		<b>Wetsuit (Steamer) (sessions = 7)</b>	
	Mean Water temp: 24.2°C ( $\pm$ 0.8)		Mean water temp: 20.0°C ( $\pm$ 0.0)	
	Mean ambient temp: 23.0°C ( $\pm$ 4.7)		Mean ambient temp: 21.6°C ( $\pm$ 4.7)	
	Mean RH: 70.1% ( $\pm$ 10.1)		Mean RH: 58.3% ( $\pm$ 13.8)	
Variable	Pre-	Post-	Pre-	Post-
Body Mass (kg) <sup>†</sup>	73.9 $\pm$ 5.1	73.0 $\pm$ 4.8	78.5 $\pm$ 9.6	77.9 $\pm$ 9.8
Urine Color (1-8)	5.9 $\pm$ 1.1	5.1 $\pm$ 2.0	4.1 $\pm$ 1.3	4.7 $\pm$ 1.3
Urine Osmolality (mOsmol/kgH <sub>2</sub> O)	668.6 $\pm$ 184.9	632.9 $\pm$ 291.2	600.0 $\pm$ 268.2	495.7 $\pm$ 220.1

<sup>†</sup>= denotes significant change (reduction) in pre- and post-surf *BM* ( $p < 0.001$ )

**Table 2.** Percentage of total time spent in each category of activity across 14 recreational surf sessions (N = 11). Values are mean ( $\pm$  *SD*)

Category	Paddling	Stationary	Misc <sup>†</sup>	Paddling for a wave	Riding a Wave	Total Surf time (min:sec)	Wave count
Total all sessions	52.0% $\pm$ 4.2	31.8% $\pm$ 4.0	9.8% $\pm$ 1.5	3.1% $\pm$ 0.5	3.1% $\pm$ 0.9	75:30 $\pm$ 5:2	12.7 $\pm$ 2.9

**Table 3.** Parameter estimates, their standard errors, 95% confidence intervals and tests of significance for effects influencing body mass (BM)

Parameter	Estimate	SE	df	t	p	L95%CI	U95%CI
Intercept	75.98	2.48	10.213	30.676	0.000	70.47	81.48
ATemp	0.55	0.11	12.400	4.810	0.000	0.30	0.79
WTime	-0.38	0.06	12.280	-6.346	0.000	-0.51	-0.25
Condition	2.53	0.51	12.324	4.967	0.000	1.42	3.64
Pre-post	-2.54	0.46	12.295	-5.487	0.000	-3.55	-1.53
ATemp * Pre-post	-0.18	0.08	12.080	-2.368	0.035	-0.34	-0.01

Retention of the significant main effects for WTime and Condition served to adjust the effects of principal interest (Pre-post and ATemp by Pre-post, as described above) for significant differences in water time between surfers, and in BM between the summer and winter cohorts (i.e., to adjust the subjects to the same session time and the same pre-session mass). The effects indicated that the surfers who spent longer on the water were on average 0.38 kg lighter per extra minute spent after 75 minutes, and the winter cohort were on average 2.53 kg heavier than the summer cohort. Estimates for the random effects (residual variances) were both significant (between-subjects  $p = 0.014$ , within subjects  $p = 0.026$ ).

### Urine Color

All potential predictors of Ucol were eliminated in the model reduction process, indicating that there were no significant ( $p < 0.05$ ) predictors of change in Ucol from pre- to post-session.

### Urine Osmolality

Only one significant effect remained after the model reduction process, with a significant interaction effect between the change from pre- to post-session and ambient temperature. The parameter estimates for the fixed effects with standard errors, tests of significance and 95% confidence intervals for the final model are reported in Table 4. The ATemp by Pre-post effect indicated that the reduction in Uosm from pre- to post-session decreased as ambient temperature rose. The Pre-post effect in Table 4 was not significant, indicating that no significant reduction in Uosm occurred pre- to post-session ( $p = 0.321$ ) at 22°C.

**Table 4.** Parameter estimates, their standard errors, 95% confidence intervals and tests of significance for effects influencing urine osmolality (Uosm)

Parameter	Estimate	SE	df	t	p	L95%CI	U95%CI
Intercept	562.34	77.36	12.87	7.27	0.000	395.04	729.65
ATemp	-19.89	13.36	20.27	-1.49	0.152	-47.73	7.95
Pre-post	-61.58	60.28	17.66	-1.02	0.321	-188.39	65.24
ATemp * Pre-post	31.00	11.45	14.49	2.71	0.017	6.53	55.48

### Discussion

The aim of the present study was to determine the extent of fluid loss experienced during a recreational surfing session and to examine variables that may be related to that loss. This was an observational study that used three common methods for measuring hydration status. Pre- and post-changes in BM, Ucol, and Uosm were recorded across 14 surf sessions in varying conditions. To our knowledge this was the first analysis of this kind in this sport.

Findings of the present study indicated a significant decrease in BM was experienced following recreational surfing sessions lasting ~75 minutes which occurred regardless of the surfing conditions or Condition (i.e., board shorts or wetsuit). This should not be surprising, given the physical demands of this form of recreation (Farley, Abbiss & Sheppard, 2016). The time spent in the various categories of physical activity observed in this study are consistent with those reported previously (e.g., Loveless & Minahan, 2010; Barlow et al., 2014). Notwithstanding this, it should be stressed that the maximum time spent in the water by any participant in this study was just 82 minutes (range = 68:51 to 82:19 mins), which is considerably shorter than the surf times reported in previous literature (Meir et al., 2012). As a result, the values reported in this study should be seen as conservative indicators of the magnitude of fluid loss experienced during a recreational surf session. Based on the results reported here, we speculated that recreational surfers have the potential to lose ~2% or more of their BM when surfing for extended periods (i.e., >75 min.).

Decreases of  $\geq 2\%$  BM are considered to be the threshold at which the negative effects of fluid loss will impair performance (Maughan & Shirreffs, 2010b; Chevront, Fraser, Kenefick, & Sawka, 2011). Some literature has suggested BM changes equivalent to just 1% of BM are sufficient to produce a negative impact on performance (Maughan, Leiper, & Shirreffs, 1997). Measurement of pre- and post-surf BM is a simple, non-invasive measure that can be used to estimate fluid loss. However, urine excretion and fluid intake must be accounted for (Harvey et al., 2008; O'Hara et al., 2010; Phillips, Sykes, & Gibson, 2014). As a result, it is recommended that BM changes be used as a suitable estimate of fluid status following recreational surfing. Practically, this

is a simple metric that should be easily accessible by recreational surfers. Furthermore, competitive surfers would benefit from using this strategy to monitor their hydration status, particularly when competing in multiple heats in a single day and across consecutive days of competition.

The current study reported no significant changes in Ucol between pre- and post-surf scores, irrespective of the environmental conditions, suggesting that the rate of fluid loss remained constant over the time period in the water. Relying on such a measure (Ucol) may not be the best approach for recreational surfers since it has been found to have some shortcomings (e.g., Driksell & Wolinsky, 2011; Harvey et al., 2008). Indeed, Shirreffs (2003) found Ucol to be less effective as an acute measurement of fluid status because it was somewhat delayed and less sensitive when compared to plasma osmolality measures.

Uosm was found to not vary between pre- and post-surf samples. Some literature has suggested an increase in osmolality should be expected following exercise due to increased concentration of urine samples (Armstrong et al., 1994; Shirreffs, 2003) although, as with Ucol changes, Uosm can often be delayed in response to changes in fluid status. As a result, Shirreffs (2003) stated Uosm was an adequate measure of hydration status where high levels of precision are not required. Ultimately, for recreational surfers the issue is one primarily of practicality. On this basis, recording measures such as Ucol and Uosm is clearly problematic in such a sport. Further, these forms of assessment require a certain level of technical understanding and in the case of Uosm the availability of appropriate equipment and technical expertise associated with its use.

### **Limitations**

Notwithstanding the findings of this research, it should be noted that there were some limitations that may have influenced the results. The most significant of these is the relatively small sample size with participants surfing in a range of conditions. A larger sample of surfers participating in the same or similar conditions, both in water and ambient, would increase the generalizability of the results. In addition, participants, on average, only surfed for ~75 minutes. Evidence shows that it is not unusual for recreational surfers to spend considerably longer (e.g., 2-3 hours) in the water when the conditions allow. As a result, the evidence observed in this present study with respect to changes in BM, which is a proxy measure of fluid loss, should be seen as conservative.

Because these were recreational surfers, no attempt was made to control for ingestions of food, other than to ensure a meal had not been consumed in the 2 hours prior to each participant's session. Similarly, no attempt was made to control for fluid status upon arrival at the surf location. Given the objective of this research, it was considered important to simply let each participant arrive

for their respective session without influencing their fluid status prior to entering the water. While not evident from the statistical analysis, it could be expected that without a clear understanding of fluid status on performance, many recreational surfers simply would not know to hydrate before surfing. This is an area for future research.

As with food and fluid, ingestion of medication or supplements (e.g. vitamins) was not controlled for. However, participants were asked to indicate if they had ingested any vitamins or supplements prior to their surf session. All reported in the negative. It is not clear how long after the ingestion of food or other substances that an observable change in Ucol might take effect. In addition, it is not clear how long any such effect might be present in the body before any potential impact begins to diminish. Nevertheless, recreational surfers are likely to surf without considering these issues and their possible impact on Ucol or Uosm. Further, there was no attempt to control the environmental conditions (ambient or water) since surfers were available as the prevailing conditions and their time permitted. The ambient and water conditions reported in this research might generally be considered mild when compared with more extreme environments, where ambient and water conditions could be significantly higher or lower, depending on geographic location. This suggests that further research is needed, not only to provide more insight into the impact of warmer or cooler environmental conditions, but to also observe changes in fluid status over longer periods in the water. Further, since many recreational surfers potentially may surf more than once in a day, the possible consequence of surfing multiple sessions in the one day should be examined.

### **Conclusions**

This study has shown that changes in pre- to post-surf session BM are a suitable proxy measure of fluid loss. For the surfers in this study, recording BM change was a more practical estimate of changes in body water than urine color or osmolality. Recreational surfers are likely to experience fluid loss, but the extent to which it may occur will vary between individuals and be greater when ambient air temperatures are higher. Further, variations are likely to be influenced by factors such as pre-surf fluid status, total time spent in the water, level of activity in the water, and overall fitness level and environmental conditions. There is evidence (Meir et al., 2011) that suggested a significant number of surfers were entering the water without any form of hydration strategy. As a result, it is likely that dehydration might become a factor that produces an increasingly negative impact on surf performance with increasing time in the water.

Given the results reported here in this limited observational study, we recommend that surfing participants monitor their own hydration status both before and after surfing. This can be achieved by recording pre- and post-surf

changes in BM which is a practical low-cost strategy that may help prevent the onset of dehydration. It is also recommended that surfers adopt established guidelines from other sports and forms of physical activity and consume ~1.5 L of fluid for every kilogram of BM lost (Shirreffs & Maughan, 1998). Such a strategy might help surfers to better understand their individual fluid intake requirements during and after each surf session. This likely will become increasingly important when participating in multiple surf sessions on the same day and/or on consecutive days.

### References

- Armstrong, L.E. Hydration assessment techniques. (2005). *Nutrition Reviews*, 63(6), S40-S-54.
- Armstrong, L.E., Maresh, C.M., Castellani, J.W. Bergeron, M.F., Kenefick, R.W., LaGasse, K.E., & Riebe, D. (1994). Urinary indices of hydration status. *International Journal of Sport Nutrition*, 4(3), 265-279.
- Armstrong, L.E., Soto, J.A., Hacker, F.T. Jr., Casa, D.J., Kavouras, S.A., & Maresh C.M. (1998). Urinary indices during dehydration, exercise, and rehydration. *International Journal of Sport Nutrition*, 8(4), 345–355.
- Barlow, M.J., Gresty, K., Findlay, M., Cooke, C.B., & Davidson, C.B. (2014). The effect of wave conditions and surfer ability on performance and the physiological response of recreational surfers. *Journal of Strength and Conditioning Research*, 28(10), 2946-2953.
- Carrasco, A.J. (2008). *Effects of exercise-induced dehydration on cognitive ability, muscular endurance and surfing performance*. Unpublished Masters Thesis, Massey University, Auckland, New Zealand.
- Casa, D.J., Clarkson, P.M., & Roberts, W.O. (2005). American College of Sports Medicine roundtable on hydration and physical activity: Consensus statements. *Current Sports Medicine Reports*, 4(3), 115-127.
- Chevront, S.N., Fraser, C.G., Kenefick, R.W., & Sawka, M.N. (2011). Reference change values for monitoring dehydration. *Clinical Chemistry and Laboratory Medicine*, 49(6), 1033-1037.
- Climstein, M., Pollard, Z., Furness, J., Walsh, J., & McLellan, C. (2015). Effects of long-term surfing on bone health in mature-aged males, *International Journal of Aquatic Research and Education*, 9(1), 24-37.
- Cox, G.R., Broad, E.M, Riley, M.D. & Burke, L.M. (2002). Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. *Journal of Science and Medicine in Sport*, 5(3), 183-193.
- Dong, Y., & Peng, C-Y.J (2013). Principled missing data methods for researchers. *SpringerPlus*, 2:222, 1-17.
- Driskell, J.A., & Wolinsky, I. (2011). *Nutritional Assessment of Athletes* (pp. 341-374) (2<sup>nd</sup> ed.). Boca Raton: CRC Press.
- Eijsvogels, T.M.H., Scholten, R.R., Duijnhoven, N.T.L., Thijssen, D.H., & Hopman, M.T. (2013). Sex difference in fluid balance responses during

- prolonged exercise. *Scandinavian Journal of Medicine and Science in Sports*, 23(2), 198-206.
- Falk, B. (1998). Effects of thermal stress during rest and exercise in the paediatric population. *Sports Medicine*, 25(4), 221-240.
- Farley, O.R.L., Abbiss, C.R., & Sheppard, J.M. (2016). Testing protocols for profiling of surfers' anaerobic and aerobic fitness: A review. *Strength and Conditioning Journal*, 38(5), 52-65.
- Farley, O.R.L., Harris, N.K., & Kilding, A.E. (2012). Physiological demands of competitive surfing. *Journal of Strength and Conditioning Research*, 26(7), 1887-1896.
- Ftaiti, F., Grélot, L., Coudreuse, J.M., & Nicol, C. (2001). Combined effect of heat stress, dehydration and exercise on neuromuscular function in humans. *European Journal of Applied Physiology*, 84(1-2), 87-94.
- Hargreaves, M. (2008). Physiological limits to exercise performance in the heat. *Journal of Science and Medicine in Sport*, 11(1), 66-71.
- Harvey, G., Meir, R., Brooks, L., & Holloway, K. (2008). The use of body mass changes as a practical measure of dehydration in team sports. *Journal of Science and Medicine in Sport*, 11(6), 600-603.
- Henkin, S.D., Sehl, P.L. & Meyer, F. (2010). Sweat rate and electrolyte concentration in swimmers, runners, and nonathletes. *International Journal of Sports Physiology and Performance*, 5(3), 359-366.
- Kenefick, R.W., & Cheuvront, S.N. (2012). Hydration for recreational sport and physical activity. *Nutrition Reviews*, 70(Suppl 2), S137-S142.
- Kerslake, D.McK. (1972). *The stress of hot environments* (pp. 1-14). London: Cambridge University Press.
- Kovacs, E.M., Senden, J.M., & Brouns, F. (1999). Urine color, osmolality and specific electrical conductance are not accurate measures of hydration status during postexercise rehydration. *Journal of Sports Medicine and Physical Fitness*, 39(1), 47-53.
- Loveless, D.J., & Minahan C. (2010). Peak power and paddling efficiency in recreational and competitive junior and male surfers. *European Journal of Sport Science*, 10(6), 407-415.
- McArdle, W.D., Katch F.I., & Katch, V.L. (2010). *Exercise Physiology: Nutrition, energy, and human performance* (pp. 611-639) (7<sup>th</sup> ed.). Philadelphia: Lippincott Williams and Watkins.
- McMurray, R.G., & Horvath, S.M. (1979). Thermoregulation in swimmers and runners. *Journal of Applied Physiology*, 46(6), 1086-1092.
- Maughan, R.J., Leiper, J.B., & Shirreffs, S.M. (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. *British Journal of Sports Medicine*, 31(3), 175-182. 1997.
- Maughan, R.J., & Shirreffs, S.M. (2010a). Dehydration and rehydration in competitive sport. *Scandinavian Journal of Medicine and Science in Sports*, 20(Suppl 3), 40-47.
- Maughan, R.J., & Shirreffs, S.M. (2010b). Development of hydration strategies to optimize performance for athletes in high-intensity sports and in

- sports with repeated intense efforts. *Scandinavian Journal of Medicine and Science in Sports*, 20(Suppl 2), 59-69.
- Meir, R., Brooks, L., & Rogerson, S. (2011). What do changes in pre-match versus post-match, 1, 2 and 3 days post-match body weight tell us about fluid status in English Premiership rugby union players? *Journal of Strength and Conditioning Research*, 25(8), 2337-2343.
- Meir, R.A., Lowdon, B.J., & Davie, A.J. (1991). Heart rates and estimated energy expenditure during recreational surfing. *The Australian Journal of Science and Medicine in Sport*, 23(3), 70-74.
- Meir, R., Zhou, S., Gilleard, W., & Coutts, R. (May 2011). *An investigation of surf participation and injury prevalence in Australian surfers: A self-reported retrospective analysis*. A report to the NSW Sporting Injuries Committee. A copy of this report can be accessed at: [https://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1901&context=hahs\\_pubs](https://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1901&context=hahs_pubs)
- Meir, R., Zhou, S., Rolfe, M., Gilleard, W., & Coutts, R. (2012). An investigation of surf injury prevalence in Australian surfers: A self-reported retrospective analysis. *New Zealand Journal of Sports Medicine*, 39(2), 52-58.
- Meir, R., Zhou, S., Rolfe, M., Gilleard, W., & Coutts, R. (2015). Self-reported sun protection strategies among Australian surfers: Are they heeding the message? *New Zealand Journal of Sport Medicine*, 42(2), 50-55.
- Mendez-Villanueva A., & Bishop D. (2005). Physiological aspects of surfboard riding performance. *Sports Medicine*, 35(1), 55-70.
- O'Hara, J.P., Jones, B.L., Tsakirides, C. Carroll, S., Cooke, C.B., & King, R.F. (2010). Hydration status of rugby league players during home match play throughout the 2008 Super League season. *Applied Physiology, Nutrition and Metabolism*, 35(6), 790-796.
- Phillips, S.M., Sykes, D., & Gibson, N. (2014). Hydration status and fluid balance of elite European youth soccer players during consecutive training sessions. *Journal of Sports Science and Medicine*, 13(4), 817-822.
- Pinheiro J.C., & Bates, D.M. (2009). *Mixed-Effects Models in S and S-Plus* (pp. 133-200). New York: Springer-Verlag.
- Prado, E.S., da Silva Barroso, S., Góis H.O., & Reinert, T. (2009). Hydration state in swimmers after three different forms of hydric replacement in the city of Aracaju – SE – Brazil. *Fitness and Performance Journal* (Online Edition), 8(3), 218-225.
- Sawka, M.N., Burke, L.M., Eichner, E.R., Maughan, R.J., Montain, S.J., & Stachendorf, N.S. (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. *Medicine and Science in Sports and Exercise*, 39(2), 377-390.
- Shirreffs, S.M. (2003). Markers of hydration status. *European Journal of Clinical Nutrition*, 57(Suppl 2), S6-S9.

- Shirreffs, S.M., & Maughan, R.J. (1998). Urine osmolality and conductivity as indices of hydration status in athletes in the heat. *Medicine and Science in Sports and Exercise*, 30(11), 1598-1602.
- Silverthorn, D.U. (2010). *Human physiology: An integrated approach* (pp. 747-752) (5th ed.). San Francisco: Pearson Benjamin Cummings.
- UCLA: Statistical Consulting Group. *Introduction to Linear Mixed Models*. Retrieved from <https://stats.idre.ucla.edu/other/mult-pkg/introduction-to-linear-mixed-models/> July 16, 2019.