International Journal of EXERCISE SCIENCE

Original Research

Fluid Loss in Recreational Surfers

JESSICA K. ATENCIO†1, RICHARD F. ARMENTA‡1, JEFF A. NESSLER‡1, MATTHEW M. SCHUBERT‡1, JAMES W. FURNESS‡2, MIKE CLIMSTEIN‡3,4, LEON MACH‡5, and SEAN C. NEWCOMER‡1

[1]Department of Kinesiology, California State University-San Marcos, San Marcos, CA, USA; [2]Water Based Research Unit, Faculty of Health Sciences and Medicine, Bond University, Gold Coast, AUSTRALIA; [3]School of Health and Human Sciences, Southern Cross University, Gold Coast, AUSTRALIA; [4]Physical Activity, Lifestyle, Aging, and Wellbeing Faculty Research Group, University of Sydney, Sydney, NSW, AUSTRALIA; [5]Tropical Island Biodiversity Studies, School for Field Studies, Bocas del Toro, PANAMA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 14(6): 423-434, 2021. Surfing offers unique challenges to thermoregulation and hydration. The purpose of this study was to quantify fluid loss in recreational surfers, and to analyze the effects of water temperature, air temperature, exercise intensity, duration, and garment thickness on the total amount of fluid lost during a surf session. A total of 254 male and 52 female recreational surfers were recruited from San Diego, Costa Rica, and Australia to participate in the study. Participants' hydration status was assessed by comparing nude body mass pre- and post-surf session. Heart rate (HR), used as an index of exercise intensity, was measured throughout the session. Environmental conditions and surf characteristics were recorded. The difference between average pre-mass (73.11 ± 11.88 kg) and average post-mass (72.51 ± 11.78) was statistically significant (0.60 ± 0.55, $p < 0.001$). Surfers experienced a 0.82 ± 0.73% reduction in body mass. In multivariable linear regression, session duration and body mass index (BMI) were significantly associated with fluid loss. For every 10-minute increase in session duration, there was a 0.06 kg (SE = 0.001; $p < 0.001$) increase in fluid loss, and for every two unit increase in BMI, fluid loss increased by 0.05 kg (SE = 0.03; $p = 0.02$). Results suggest that prolonged surfing at high environmental temperatures in participants with high BMI's resulted in significant body water deficits. Since there is no opportunity to rehydrate during a surf session, surfers must properly pre-hydrate before surfing in order to avoid the detrimental effects of dehydration.

KEY WORDS: Dehydration, action sports, sweating.

INTRODUCTION

Hydration status is often evaluated by measuring pre- and post-activity body mass to determine the amount of water lost by an athlete (3). A body mass deficit of 2% or greater is the level of dehydration at which exercise performance becomes compromised, as shown by deficits in aerobic, cognitive and motor functioning, with deficits to health and performance becoming more severe as body mass deficits increase (3, 16, 18). Therefore, proper hydration is necessary in order to avoid water deficits that may lead to impaired exercise performance or the development of heat injury (15).

In land-based sports such as soccer, athletes experience significant dehydration with body mass deficits reaching over 2%. Other sports, such as American football and basketball also report high rates of perspiration. However, drinking opportunities are often sufficient to offset fluid losses (14). Exercise in the aquatic environment is unique when compared to land-based exercise due to the body being immersed in water, leading to skin temperatures becoming congruent with water temperatures (18). In contrast to dissipating heat through sweat, athletes participating in aquatic sports are more able to utilize convection and conduction for heat transfer when skin temperature exceeds water temperature (4). Although aqueous environments limit the body's ability to dissipate heat through sweat, research suggests that participation in aquatic sports leads to fluid deficits. In a study conducted by Cox et al. (4), competitive male and female swimmers experienced a 0.11% and 0.14% reduction in body mass due to activity, respectively. The minimal body mass deficits experienced by participants are due to their mean fluid intake rates closely matching their mean sweat rates. It is recommended by the American College of Sports Medicine (ACSM) that during exercise, athletes should start consuming water early and at regular intervals in order to replace fluids lost through sweating (15). While athletes participating in most aquatic sports are able to rehydrate during activity, the sport of surfing is unique due to the fact that there is little to no opportunity for surfers to rehydrate during the activity.

Surfing can be accomplished in a variety of climates, ranging from arctic to tropical, with the reported intensity of surf practice being between 70-80% peak heart rate (9, 12) and participation of up to 5 hours (12). Although heat exchange in water sports occurs mainly through conduction and convection, increases in water temperature and exercise intensity induce a rise in body temperature, which can result in substantial fluid loss through sweating (7). In addition, surfers wear wetsuits to reduce convective heat loss due to cold-water exposure (21). This thermal insulation, however, may result in a decreased ability for the surfer to maintain core temperature and dissipate metabolic heat via conduction and convection, potentially resulting in increased sweat rates. It is widely accepted that hours of continuous moderate-intensity exercise, in hot environments with limited fluid intake, will lead to dehydration (2, 5).

With the reported detrimental effects on both performance and health parameters, it is important to understand the effects of surfing activity on hydration. To date, minimal research has investigated the hydration status of recreational surfers. Studies investigating fluid loss in recreational surfers have suggested that surfers are not properly hydrating before entering the water, and surf practice results in body mass deficits severe enough to impair surfing performance (2, 8). Based on the results of these studies and their limited sample sizes, it is unclear the role that environmental conditions, garments, and exercise intensity have on fluid loss in surfing and whether the sport of surfing poses a risk of dehydration in a generalizable sample.

Surfing can be accomplished in warm water and air temperatures, is physically demanding, and protective garments are worn that may in fact exacerbate fluid loss; therefore, it is important to consider the risk of dehydration in the sport of surfing. The purpose of this study was to examine the relationship between water temperature, air temperature, exercise intensity, exercise duration, and different garments worn during surfing to the amount of fluid lost in recreational surfers during a surf session. We hypothesized that increases in exercise intensity, water and air temperature, and wetsuit thickness would be positively correlated to the amount of fluid lost during recreational surfing.

METHODS

Participants

A power analyses conducted using G*POWER 3.1.9 (Universität Düsseldorf, Germany) determined that a sample size of 207 participants was needed in the present study for a power of 0.80, with an effect size of 0.2 and an $\alpha = 0.05$. A total of 306 recreational surfers (male = 254, female = 52), 18-65 years old, with at least one year of surfing experience volunteered to participate in this study. An international, multi-site study was conducted, and participants were recruited from North County San Diego, the Guanacaste peninsula of Costa Rica, and the Gold Coast of Australia in order to explore the effects of environmental factors (ambient temperature, water temperature, and humidity) on hydration status. Data was collected in San Diego from March to May (spring), from Australia during December and January (summer), and from Costa Rica during the month of May (summer). Prior to participation, participants were informed of the risks and benefits of the investigation and were asked to provide written informed consent. Participants were excluded if they had less than one year of surfing experience, as their skills are not an accurate representation of the activities that experienced surfers perform in the water. All procedures were approved by the Institutional Review Board at California State University, San Marcos (IRB# 1205906). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (13).

Protocol

Following recruitment, participants completed a brief questionnaire that assessed self-reported height, years of surfing experience, surfing frequency (hours per week), board height (inches), fin set up (single fin, twin fin, etc.), and wetsuit type and thickness (mm) (skin/rash guard, wetsuit ≤ 3mm, or wetsuit ≥ 3mm). Prior to pre-mass measurements, participants were asked to void the body of urine in order to prevent fluid loss due to urination in the water during the surf session. This measure was taken because during land-based exercise urine excretion is suppressed due to antidiuretic hormone (ADH) and aldosterone (1). In aquatic environments, however, the hydrostatic pressure can expand plasma volume and decrease peripheral blood pooling, leading to the suppression of ADH and an increase in the output of dilute urine (1, 15). Participants were also asked to wet their hair in order to mimic the mass of their saturated hair following the surf session. Three measurements of nude mass (kg) to the nearest 0.1 kg using a portable scale (SECA, CA, USA) on a leveled surface were measured and recorded for each participant. The average of the three mass measurements was recorded as their body mass prior to the surf session. Following pre-surf body mass measurement, participants were fitted with a Polar T31 heart rate (HR) sensor and Polar FT1 HR monitor receiver (Polar Electro Inc., NY, USA) around their sternum and wrist, respectively, in order to measure HR throughout the session. Participants were then instructed to participate in their normal surfing activity while utilizing their own surfing equipment. The starting time of their surf session was recorded prior to them entering the water.

Environmental and surf conditions, including air and water temperature, wind speed and direction, wave height, wave interval, and wave direction, were recorded in correlation to the beach and time that the data collection occurred using information directly from the National Oceanic and Atmospheric Administration's buoys located offshore (Surfline.com). Relative humidity was collected from Weather.com. Upon completion of the surf session, subjects' end time and average HR throughout the surf session were recorded. After towel drying, three more measurements of nude body mass were taken, and the average of the three measurements was recorded as their post-activity body mass. Average pre-mass and average post-mass of each subject was used to calculate total fluid loss during a surf session by subtracting post-mass from pre-mass. Each subject's percent change in body mass was calculated using the following formula (4):

$$\%\text{ change in BM} = \frac{[\text{Post-exercise body mass (g)} - \text{pre-exercise body mass (g)}] \times 100}{\text{Pre-exercise body mass (g)}}$$

Statistical Analysis

Means and standard deviations were used to describe participant characteristics for continuous variables and proportions were used for categorical variables. T-tests were used to compare characteristics by sex (male compared to female). A paired t-test was used to assess pre- and post-surf session mass (fluid loss). One-way ANOVA was used to compare environmental conditions between San Diego, Costa Rica, and Australia and Tukey's post hoc test was used to compare differences between locations. Overall fluid loss was described using mean and standard deviation and factors associated with fluid loss were determined using bivariate linear regression. Multivariable linear regression was then used to determine factors independently associated with total fluid loss during a surf session. Multicollinearity was assessed using variance inflation factors and was not detected. No significant outliers were detected by exploring data points 1.5 times outside of the interquartile range. Test assumption were examined through visual inspection and Q-Q plots. All data analyses were conducted using SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Statistical significance was set at $p < 0.05$.

RESULTS

Table 1: Demographic and surf characteristics of male and female participants.

	Male (mean ± SD: n=254)	Female (mean ± SD: n=52)	Total (mean ± SD: n=306)	p-value
Demographics				
Age (years)	35.4 ± 10.8	29.94 ± 7.5	34.4 ± 10.5	0.001
Height (m)	1.78 ± 0.09	1.67 ± 0.07	1.76 ± 0.10	<0.001
Weight (kg)	76.04 ± 10.50	58.78 ± 6.75	73.11 ± 11.88	<0.001
BMI (kg/m²)	24.14 ± 3.31	21.18 ± 2.27	23.64 ± 3.34	<0.001
Surf characteristics				
Years surfed	16.30 ± 11.14	9.36 ± 6.75	15.13 ± 10.84	<0.001
Hours per week	8.06 ± 6.91	6.81 ± 5.72	7.85 ± 6.73	0.221
Competency (1-10)	6.20 ± 1.64	5.15 ± 1.67	6.02 ± 1.69	<0.001
Board length (m)	2.05 ± 0.53	2.07 ± 0.44	2.05 ± 0.51	0.760
Garment type*				
Skin/Rashguard	142 (82%)	30 (18%)	172 (56%)	<0.001
Wetsuit ≤ 3mm	39 (87%)	6 (13%)	45 (15%)	<0.001
Wetsuit (Full) ≥ 3mm	73 (82%)	16 (18%)	89 (29%)	<0.001

*Surf garments were classified according to thickness in millimeters and amount of coverage provided. Wetsuit ≤ 3 mm included vests and springsuits that were ≤ 3 mm thick, and did not provide full body coverage. Wetsuit ≥ 3mm included fullsuit wetsuits that were ≥ 3mm thick and provided full-body coverage. kg=kilograms, m=meters, kg/m²=kilograms/meters², in=inches, mm=millimeteres.

Subject characteristics are reported in Table 1. A total of 306 participants (M = 254, F = 52) participated in the study with a mean age, height, mass, and body mass index (BMI) of 34.4 ± 10.5 years, 1.76 ± 0.11 m, 72.91 ± 12.34 kg, and 23.60 ± 3.41 kg/m², respectively. There were significant differences between sexes in all demographic and surf characteristics except for hours surfed per week and board length.

Table 2: Environmental characteristics of the three locations data collection occurred.

	San Diego (n = 96)	Australia (n = 52)	Costa Rica (n = 158)
Water temperature (ºC)	16.84 ± 1.75*	24.87 ± 0.96+	28.62 ± 0.91¥
Air temperature (ºC)	17.44 ± 2.81*	25.96 ± 2.25+	29.30 ± 3.61¥
Relative humidity (%)	60.02 ± 17.60*	69.48 ± 9.04	72.51 ± 15.96¥

*Indicates a significant difference ($p < 0.05$) between San Diego and Australia, ¥Indicates a significant difference ($p < 0.05$) between San Diego and Costa Rica, +Indicates a significant difference ($p < 0.05$) between Costa Rica and Australia from Tukey Post-hoc test.

Table 2 represents the environmental conditions participants were exposed to at each location. Post hoc analyses revealed that water temperature and air temperature were significantly different between San Diego, Costa Rica, and Australia. A significant difference between San Diego and Costa Rica, as well as San Diego and Australia, was observed for relative humidity. There was no significant difference in relative humidity between Costa Rica and Australia

Table 3: Fluid loss outcomes following a completed surf session.

	Male (mean ± SD: *n* = 254)	Female (mean ± SD: *n* = 52)	Total (mean ± SD: *n* = 306)	p-value
Pre-Weight (kg)	76.04 ± 10.50	58.78 ± 6.75	73.11 ± 11.88	<0.001
Post-Weight (kg)	75.40 ± 10.43	58.38 ± 6.73	72.51 ± 11.78	<0.001
Fluid loss (kg)	0.64 ± 0.57	0.40 ± 0.38	0.60 ± 0.55	0.004
Sweat rate (kg/hr)	0.45 ± 0.40	0.34 ± 0.35	0.43 ± 0.40	<0.001
Percent change (%)	0.84 ± 0.75	0.68 ± 0.63	0.82 ± 0.73	0.159

Subject fluid loss outcomes are reported in Table 3. The average duration of the surf session was 82.69 ± 33.97 minutes and participants had average heart rates of 125.47 ± 15.91 bpm throughout the session. There were no significant differences observed between sexes for duration of the surf session or heart rate throughout the surf session. There was a statistically significant difference between men and women for total fluid loss observed and sweat rate (Table 3). The difference between pre- and post-mass was statistically significant, with a mean body mass loss of 0.82% ± 0.73 (Table 3).

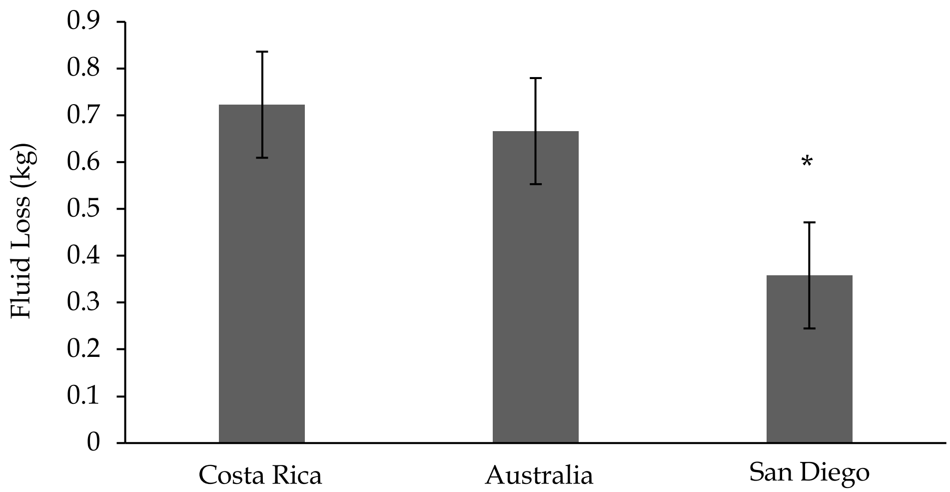

Figure 1: Average fluid loss (kg) of surfers in all three locations where data collection occurred. Error bars represent standard errors. Asterisk (*) indicates a significant difference between San Diego, and Costa Rica and Australia as derived from Tukey's post hoc test.

A significant difference between location and fluid loss was observed between Costa Rica and San Diego ($p < 0.001$), and Australia and San Diego ($p = 0.001$). However, there was no significant difference observed for fluid loss between Costa Rica and Australia (Figure 1). On average, participants in Costa Rica lost 0.72 ± 0.60 kg of fluid (0.98% ± 0.78), participants in Australia lost 0.67 ± 0.46 kg of fluid (0.94% ± 0.66), and participants in San Diego lost 0.36 ± 0.43 kg of fluid (0.48% ± 0.55) (Figure 1).

Table 4: Factors associated with fluid loss (kg) among recreational surfers (n = 306).

Factors	Unadjusted Beta (SE)	p-value	Adjusted Beta (SE)	p-value
Costa Rica vs. San Diego	0.308 (0.091)	<0.001	0.226 (0.164)	0.447
Australia vs. San Diego	0.363 (0.069)	<0.001	0.106 (0.139)	0.170
Air Temp (ºC)	0.021 (0.005)	<0.001	-0.007 (0.011)	0.516
Humidity (%)	0.004 (0.002)	0.033	-0.002 (0.002)	0.853
Heart Rate (bpm)	0.002 (0.002)	0.291	0.002 (0.002)	0.345

Table 4 shows bivariate and multivariable associations between demographic, surf, and environmental characteristics and fluid loss. Factors associated with fluid loss were determined using multivariable linear regression. Session duration and BMI were associated with fluid loss (Table 4). For every 20-minute increase in session duration, there was a 0.14 kg (SE = .001, p < 0.001) increase in fluid loss after adjustment for other variables in the model including air temperature, humidity, water temperature, exercise intensity (HR), and BMI (Table 4). While location, a proxy for water temperature, was not significantly associated with fluid loss after adjusting for other variables in the model, there were larger amounts of fluid loss in locations with warmer water (Table 4) (Figure 1). Ambient air temperature, exercise intensity (HR), and humidity were not associated with changes in fluid loss. Additionally, for every two unit increase in BMI, fluid loss increased by 0.06 kg (SE = 0.02, p = 0.001) (Table 4). Overall, the regression model accounted for 27% (r^2 = 0.27) of the variability in fluid loss among surfers.

DISCUSSION

This study aimed to quantify fluid loss in recreational surfers and analyze the effects of environmental factors (water temperature, air temperature, and humidity) and physical factors (BMI, session duration, exercise intensity, and garment thickness) on the total amount of fluid loss observed in participants. This study demonstrates for the first time the average amount of fluid a general population of recreational surfers may lose in a typical surf session, and the factors that are associated with fluid loss in surfing. Specifically, in a sample of 306 recreational surfers, participants experienced an average fluid loss of 0.60 ± 0.55 kg or a 0.82 ± 0.73% reduction in body mass. In the warm water environments of Costa Rica and Australia, the mean fluid loss experienced by participants was 0.72 ± 0.60 kg and 0.67 ± 0.46 kg, respectively. Participants who surfed in cold water environments in San Diego lost a significantly lower amount of fluid, 0.36 ± 0.43 kg. Duration of the surf session and body composition were also associated with fluid loss, while air temperature, exercise intensity (HR), and humidity had little to no effect on fluid loss during surfing.

Our current study concludes that the average recreational surfer experiences a 0.82 ± 0.73% reduction in body mass during a surf session of approximately 82.69 ± 33.97 minutes, which would not be expected to cause significant dehydration or performance decrements. Previous research also measuring body mass loss to determine whether surfing activity results in dehydration report results consistent with our study and others conflicting. Meir et al. (8) reported that a sample of seven recreational surfers experienced a mean body mass loss of 0.90 ± 1.2% after surfing for an average of 76 minutes in water temperatures ranging from 24 - 26 ºC.

Conversely, in a study by Carrasco (2) where twelve professional surfers surfed for 100 minutes in a wetsuit, half of the participants experienced a mean body mass loss of 3.9 ± 0.7%, reaching a significant level of dehydration with likely significant decrements to health and or performance. The participants in Carrasco's study wore wetsuits in warmer conditions, 20.8 ± 1.4 ºC, compared to the average water temperature of 16.84 ± 1.75 ºC where participants wore wetsuits in our study, suggesting it is likely that the use of neoprene wetsuits in warm water conditions increases the amount of fluid loss due to increased sweat rates and energy expenditure. In addition, the participants of Carrasco's study surfed for 100 minutes whereas our participants surfed for an average of 82.69 ± 33.97 minutes. In our data analysis, we found that duration of the surf session has a strong influence on fluid loss, offering another explanation as to why a higher body mass deficit was observed in Carrasco's study. It is important to note that research has established that a body mass deficit of 2% is considered a threshold for dehydration, with adverse effects on aerobic, cognitive, and motor functioning worsening as body mass deficits increase. However, it has also been well documented that deficits as little as 1% may increase core body temperature and cardiovascular strain (15). Although our total sample reached a mean body mass deficit of 0.82 ± 0.73%, 21 of our participants reached dehydration at a level of 2% or greater deficit in body mass. In addition, a total of 117 participants (M = 101, F = 16) reached a body mass deficit of at least 1% or greater, suggesting that a large portion of our sample may have achieved levels of fluid loss that are associated with increased physiological strain and performance decrements. The present study demonstrates the average amount of fluid lost during a surf session in 306 recreational surfers practicing in a variety of environmental conditions across some of the most popular surf locations around the world: California, Costa Rica, and Australia, represent a more generalizable population when compared to the previous studies and their limited sample sizes.

Fluid loss during surfing may occur through three distinct mechanisms: sweating, urination, and/or respiration. In the current study, it is unclear the extent to which each of these mechanisms contributed to fluid loss during recreational surfing. To reduce the impact of urination on fluid loss, participants emptied their bladder prior to surfing. However, it is well known that exercise in an aquatic environment can lead to the suppression of ADH and an increase in the output of dilute urine (1, 15). Therefore, it is likely that a small percentage of the fluid loss reported in the current study may be attributed to urination during recreational surfing. On the other hand, data collected from the current study suggest that sweating during recreational surfing likely plays a more significant role in fluid loss than urination. Specifically, results from multivariable linear regression analysis found that variables that are often linked to sweating during exercise (duration, temperature, and body composition) were all significantly associated with increases in fluid loss during recreational surfing. It is widely accepted that hours of continuous exercise, in hot environments with limited fluid intake, will increase the rate of sweating and lead to dehydration (2, 5). This is consistent with the current data, which suggests that increased surfing duration and water temperature result in an increase in fluid loss. BMI is also likely to have an effect on the rate of sweating as overweight, but especially obese participants, are prone to develop fluid and sodium imbalances through increased sweat rate as a result of prolonged, moderate intensity exercise (6). A significant difference in BMI was observed in men (24.14 ± 3.31 kg/m^2) compared to women (21.18 ± 2.27

kg/m^2). Women typically have lower sweating rates than men primarily because of their smaller body size and lower metabolic rates, explaining why we observed a significant difference in fluid loss between males (0.64 ± 0.57 kg) and females (0.40 ± 0.38 kg) that surfed for similar durations and intensities (15). Given the results of this study, we can speculate that that the primary source of fluid loss during recreational surfing is through sweating with urination comprising a secondary source of fluid loss. However, future research will need to confirm these findings through direct measurements of sweating and urination during recreational surfing.

The findings of the current study are significant because they can be applied to the general surfing population. Surfers are not always cognizant that they may be losing fluid due to their body being submerged in water, however, it is important to understand the dangers of dehydration as the sport of surfing relies on decision-making, reaction time, proprioception, and information processing ability, all of which may be deteriorated due to inadequate hydration (2, 19). In colder water environments, surfers do not need to be as cautious of dehydration as they are more able to utilize convection and conduction for heat transfer, rather than through the evaporation of sweat (4). However, because traveling to different surf spots around the world is popular among the surfing population, surfers must acknowledge the dangers of dehydration if they're surfing in warmer environments, where it is much more likely for heat transfer to occur via evaporation of sweat. In addition, these warmer environments, and oftentimes better surf conditions, influence surfers to participate for a much longer period of time than they typically would, further increasing the risk of dehydration. With this considered, it is important for surfers to be properly educated on the need to hydrate pre- and post-surf session. In unpublished research by Meir et al. (10), it was reported that approximately a quarter of all surfers indicated that they "never" drank additional fluids before surfing (8). Current ACSM guidelines for land-based sports suggest that individuals consume approximately 500 ml (17 ounces) of fluid approximately two hours before exercise, and at regular intervals in order to consume fluids at a rate sufficient to replace all water lost through sweating (15). However, this may be impractical for early morning surf sessions and it is unfeasible for surfers to rehydrate while performing the sport. In order to prevent hypohydration prior to participation in early morning recreational surfing, surfers can consume 5 - 7 ml/kg of body mass before going to bed at night (15). Upon completion of a surf session, if the session was less than three hours, in a temperate environment, and neoprene garments were not used, then a normal meal and fluid intake is sufficient to achieve euhydration (17). In severe cases where > 2% body mass loss has occurred or severe dehydration is suspected, fluid should be replenished by drinking ~ 1.5 L water for every kg of body mass lost (15). Common signs of dehydration are thirst, fatigue, headache, lightheadedness, dizziness, and muscle pain (20). We suggest that surfers exit the water when they start to experience any of these symptoms.

The present study is not without some limitations. A limitation we faced in the current study was that when saturating each participant's hair prior to their pre-mass assessment, we may have over- or under-saturated their hair in an attempt to mimic the mass of their hair after exiting the water at the end of the surf session. This may have led to an overestimation or underestimation of their post-body mass and overall fluid loss. Another limitation to the study was our inability to analyze the effect of garment thickness on fluid loss. Although we hypothesized that increases in garment thickness would lead to increases in fluid loss, garment type/thickness was not analyzed due to the nature in which participants chose to wear them. Due to warmer conditions in Costa Rica and Australia that allowed for participants to surf comfortably without any protective garments compared to the cold-water environments in San Diego that required participants to wear wetsuits to reduce convective heat loss from cold water, it is not possible to adequately isolate the effects of garment thickness from water temperature, and therefore we could not analyze the effect of garment thickness on fluid loss. Exercise performed in a wetsuit may exacerbate sweat rates and subsequently body mass loss, therefore future studies will need to have surfers wear wetsuits in a controlled environment to evaluate the influence that garment thickness has on fluid loss (2). We did not measure urine specific gravity (USG) to determine if participants were truly dehydrated. While we did measure body mass deficits to determine if participants experienced fluid loss and became dehydrated, participants may have been hyperhydrated prior to testing, suggesting that they may have never reached dehydration, even if body mass deficits were observed. The American College of Sports Medicine suggests the combined use of pre- and post-body mass measurements and USG to be an effective and reliable methodology for monitoring the hydration status of athletes in the field (3, 15). Therefore, body mass should be measured in conjunction with USG for a more accurate measure of hydration status. Lastly, we were unable to characterize a surf session as our participants surfed for varying amounts of time at different average exercise intensities. However, it has been documented that surfing is comprised of 45% to 50% paddling, 35% to 45% stationary, and the remaining time spent wave riding and performing other activities such as duck diving (12).

In conclusion, this study was the first to demonstrate that among 306 recreational surfers, surfing activity results in an average body mass deficit of 0.82 ± 0.73%, and consequently a mild level of dehydration with no decrements to health or performance. However, 117 of our participants reached dehydration at a level of 1% or greater, suggesting that slight deficits to health and/or performance may have occurred in these participants. Based on our data, we determined that water temperature, duration, and body composition all have a significant impact on the amount of fluid lost during surfing activity, with the most significant fluid losses occurring in the warmer environments of Costa Rica (0.98% ± 0.78) and Australia (0.94% ± 0.66). Given the results of our study, when surfers know they will be surfing for a prolonged period of time in high environmental temperatures, the need for an adequate level of hydration prior to entering the water is essential. Since there is no opportunity to replenish any fluid lost through sweating while surfing, surfers must be educated on the need to hydrate prior to surfing, the warning signs of dehydration, and when to exit the water in order to rehydrate.

ACKNOWLEDGEMENTS

This study was designed by J. Atencio, S. Newcomer, J. Nessler and J. Furness; the data were collected and analyzed by J. Atencio, S. Newcomer, R. Armenta, J. Furness, M. Climstein, and L. Mach. Data interpretation was undertaken by J. Atencio, S. Newcomer, and R. Armenta. All authors participated in manuscript preparation and approved the final version of the paper. The authors would like to thank all the participants who volunteered to take part in this study, as well as the students from the Kinesiology 326 undergraduate class for their help with data collection. The authors declare no conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

1. Böning D, Mrugalla M, Maassen N, Busse M, Wagner TO. Exercise versus immersion: antagonistic effects on water and electrolyte metabolism during swimming. Eur J Appl Physiol Occup Physiol 57(2): 248-53, 1988.

2. Carrasco AJ. Effects of exercise-induced dehydration on cognitive ability, muscular endurance, and surfing performance: A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Sport and Exercise Science. Auckland, New Zealand: Massey University; 2008.

3. Casa DJ, Clarkson PM, Roberts WO. American College of Sports Medicine roundtable on hydration and physical activity: Consensus statements. Curr Sports Med Rep 4(3): 115-127, 2005.

4. Cox GR, Broad EM, Riley MD, Burke LM. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. J Sci Med Sport 5(3): 183-93, 2002.

5. Coyle EF, Montain SJ. Benefits of fluid replacement with carbohydrate during exercise. Med Sci Sports Exerc 24(9 Suppl): S324-30, 1992.

6. Eijsvogels TM, Veltmeijer MT, Schreuder TH, Poelkens F, Thijssen DH, Hopman MT. The impact of obesity on physiological responses during prolonged exercise. Int J Obes (Lond) 35(11): 1404-12, 2011.

7. Macaluso F, Felice VD, Boscaino G, Bonsignore G, Stampone T, Farina F, Morici G. Effects of three different water temperatures on dehydration in competitive swimmers. Sci Sports 26(5): 265–271, 2011.

8. Meir R, Duncan B, Crowley-McHattan Z, Gorrie C, Sheppard J. Water, water, everywhere, nor any drop to drink: fluid loss in Australian recreational surfers. J Aust Strength Cond 23(6): 16-20, 2015.

9. Meir RA, Lowdon BJ, Davie AJ. Heart rates and estimated energy expenditure during recreational surfing. Aust J Sci Med Sport 23(3): 70-74, 1991.

10. Meir R, Zhou S, Gilleard W, Coutts R. An investigation of surf participation and injury prevalence in Australian surfers: A self-reported retrospective analysis. A report to the News South Wales Sporting Injuries Committee, May, 2011.

11. Méndez-Villanueva A, Perez-Landaluce J, Bishop D, Fernandez-García B, Ortolano R, Leibar X, Terrados N. Upper body aerobic fitness comparison between two groups of competitive surfboard riders. J Sci Med Sport 8(1): 43-51, 2005.

12. Mendez-Villanueva A, Bishop D. Physiological aspects of surfboard riding performance. Sports Med 35(1): 55-70, 2005.

13. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

14. Nuccio RP, Barnes KA, Carter JM, Baker LB. Fluid balance in team sport athletes and the effect of hypohydration on cognitive, technical, and physical performance. Sports Med 47(10): 1951-1982, 2017.

15. 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.

16. Sawka, MN, Cheuvront SN, Kenefick RW. Hypohydration and human Performance: Impact of environment and physiological mechanisms. Sports Med 45(S1): 51-60, 2015.

17. Shaw G, Koivisto A, Gerrard D, Burke LM. Nutrition considerations for open-water swimming. Int J Sport Nutr Exerc Metab 24(4): 373-81, 2014.

18. Sinclair W, Marshall NJ. Hydration status of lifesaving athletes during international competition. Int J Aquat Res Educ 6(4): 294-302, 2012.

19. Smith MS, Dyson R, Hale T, Harrison JH, McManus P. The effects in humans of rapid loss of body mass on a boxing-related task. Eur J Appl Physiol 83(1): 34-9, 2000.

20. Taylor K, Jones EB. Adult dehydration. Treasure Island, FL: StatPearls Publishing; 2020.

21. Wakabayashi H, Hanai A, Yokoyama S, Nomura T. Thermal insulation and body temperature wearing a thermal swimsuit during water immersion. J Physiol Anthropol 25(5): 331-338, 2006.