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Comparison of hot water immersion at self-adjusted maximum tolerable temperature, with or without the addition of salt, for rapid weight loss in mixed martial arts athletes

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ABSTRACT: Hot water immersion is used by athletes in weight category sports to produce rapid weight loss (RWL) by means of passive fluid loss, and often is performed with the addition of Epsom salts (magnesium sulphate). This study investigated the magnitude of body mass losses during hot water immersion with or without the addition of salt, with the temperature commencing at 37.8°C and being self-adjusted by participants to their maximum tolerable temperature. In a crossover design, eight male MMA athletes (29.4 ± 5.3 y; 1.83 ± 0.05 m; 85.0 ± 4.9 kg) performed a 20 min whole-body immersion followed by a 40 min wrap in a warm room, twice in sequence per visit. During one visit, only fresh water was used (FWB), and in the other visit, magnesium sulphate (1.6% wt/vol) was added to the bath (SWB). Prior to each visit, 24 h of carbohydrate, fibre and fluid restriction was undertaken. Water temperatures at the end of the first and second baths were ~39.0°C and ~39.5°C, respectively. Body mass losses induced by the hot bath protocols were 1.71 ± 0.70 kg and 1.66 ± 0.78 kg for FWB and SWB, respectively (P = 0.867 between trials, d = 0.07), and equivalent to ~2.0% body mass. Body mass lost during the entire RWL protocol was 4.5 ± 0.7%. Under the conditions employed, the magnitude of body mass lost in SWB was similar to FWB. Augmenting passive fluid loss during hot water immersion with the addition of salt may require a higher salt concentration than that presently utilised.

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INTRODUCTION

Rapid weight loss (RWL) is frequently practiced in sports that have weight class restrictions [1, 2]. For example, in mixed martial arts (MMA), the percentage of body mass lost by these athletes is usually ~5% to 10% in the week prior to competition [3–9]. To achieve losses of this magnitude, RWL strategies that reduce body water stores (e.g. water loading, fluid restriction, and increasing sweat losses through heat exposure) are the predominant methods of RWL [4, 5, 9].

A means of passive fluid loss known as hot baths is often employed as part of weight-making practices in combat sports [3, 9–13]. A recent survey of RWL practices by MMA athletes reported the use of hot baths to be highly prevalent, with 76% of fighters reporting their use either "always" or "sometimes" [9]. Hot baths generally describe the practice of hot water immersion followed by wrapping in warm clothing for a period of time prior to further exposures to hot water immersion and wrapping. However, there are large variations in how athletes perform a hot bath protocol [14]. For instance, in a cohort of 11 fighters, duration of immersions varied from 11 to 60 min and duration of wraps varied from 6 to 60 min, and the number of combined immersions with wraps is typically two rounds for a "normal" weight cut [14]. In contrast, one case study reported nine hot baths being used in the 20 h prior to weigh-in as part of one fighter's weight cut [10].

As part of their personal hot bath protocol, many of the fighters described the addition of 1 to 2 kg of Epsom salts to the water with the aim of augmenting the loss of body mass compared to that achieved by immersion in fresh water [14]. The addition of salt to this end does have some empirical evidence to support its practice [15–17], with the suggestion that the addition of salt increases the osmotic pressure difference between the immersion medium and body fluids, and/or removes the inhibitory effect on sweating, and thereby contributes to the greater fluid loss compared to fresh water [15–20]. We recently tested the addition of Epsom salts to produce a 1.6% salt solution but found no difference in body mass losses comparing fresh water and salt water immersion when the water temperature was maintained at 37.8ºC. In the absence of previous studies in athletes, we used this fixed temperature in order to increase the internal validity of the experimental design. However, in an exit questionnaire, all but one participant found our bathing protocol at 37.8ºC to be colder than the hot water immersion that they usually employ, and all participants reported that they usually increase the water temperature throughout each immersion, either using hot tap water or boiled kettle water. Therefore, in practice in MMA, a hot bath protocol is completed by starting at a warm water temperature and increasing temperature to the fighter's maximum tolerable temperature. This difference in protocol compared to our recent experiment is salient because there is a suggestion from previous work that water temperature and salt concentration may interact such that the effect of the addition of salt, if any, is greater at higher water temperatures [17, 19].

Therefore, the aim of the present study was to determine the magnitude of body mass losses in MMA athletes using a hot bath protocol with immersion in hot water with or without the addition of Epsom salt, and wherein participants were encouraged to increase bathing temperatures to that which they would use during their typical hot bath protocol during a weight cut.

MATERIALS AND METHODS

Participants

Eight male MMA athletes (age, 29.4 ± 5.3 y; height, 1.83 ± 0.05 m; body mass, 85.0 ± 4.9 kg) provided written informed consent to participate. Participants comprised both amateur and professional fighters, including two former Ultimate Fighting Championship (UFC) fighters. All participants were competing under professional weigh-in rules at the time of the study i.e. weigh-in 24 h before competition. Each participant had previous experience of RWL and the use of hot baths as part of that process, and each had made weight for competition on at least ten occasions prior to participation in the study. The study was approved by the Human Research Ethics Committee of Dublin City University (permit number: DCUREC/2019/115). This study protocol was based on our previous work [14], but was performed independent of that work, separated by 4 to 6 calendar months, and under a different ethics committee permit. However, n = 6 participants were common to both studies.

Protocol

A crossover-repeated measures design was employed to compare the effects on passive fluid loss of hot water immersion under conditions of fresh water bathing (FWB) compared to salt water bathing (SWB). Participants performed two main experimental trials separated by at least seven days, with the order of the FWB and SWB trials being assigned in a counterbalanced manner. The FWB and SWB trials were identical with the exception of the water condition in which they were immersed (Figure 1). On the day prior to bathing, participants were prescribed to eliminate carbohydrate- and fibre-rich foods from their diet and consume an energy intake of 22 kcal/kg body mass. Fluid intake was prescribed to be restricted to 15 mL/kg for the 24 hours before bathing. These dietary and fluid restriction

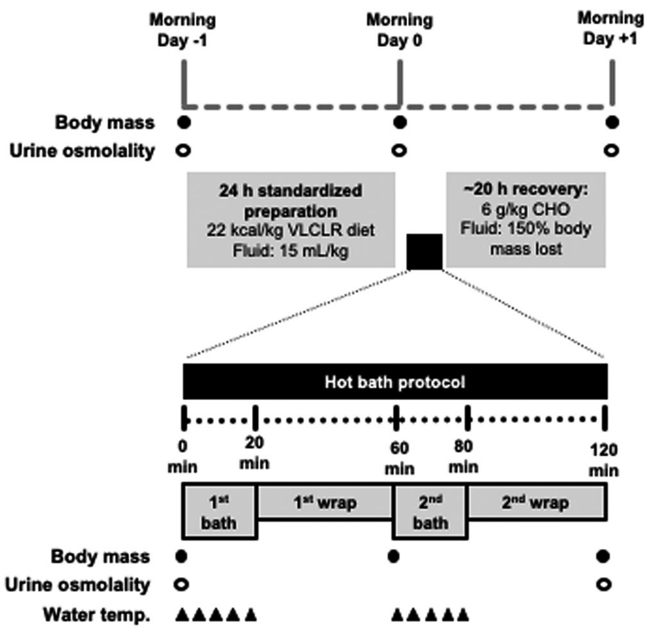

FIG. 1. Study design schematic. Experimental trials were identical with the exception of the water condition in which they were immersed being with fresh water bathing or salt water bathing on separate days. CHO, carbohydrate; VLCLR, very low carbohydrate, low residue.

protocols were typical of what was practiced by the participants in their previous RWL experiences, and compliance with the prescribed protocol was confirmed verbally on Morning Day 0. The bathing protocol was as previously described [14] and comprised of 20 min of hot water immersion ("bath") followed by 40 min wrapped in heavy clothing and blankets in a warm room ("wrap"). This 60 min bath and wrap protocol was repeated twice per main experimental trial i.e. 2 h total (Figure 1). All experiments took place in the same bath, bathroom, and adjacent bedroom of a private residential dwelling.

For each bath, participants were submerged up to the neck for 20 min. The initial water temperature of the bath was prepared to 37.8ºC, but participants were encouraged to bath in a water temperature that was typical for a normal weight cut bath protocol. In practice, this process usually involves bringing the water temperature up to a fighter's maximum tolerable level, but this temperature will vary from fighter to fighter. To achieve this aim, participants requested from the researchers for the addition of boiling water from an electric kettle (1.5 L) to the bath *ad libitum*. The volume of additional boiling water per bath was noted. A floating thermometer (Avent Bath & Room Thermometer; Philips, UK) was checked at 4 min intervals for measurement of water temperature (Figure 1), but participants were not informed of the temperature during either bath or trial.

After 20 min of bathing, participants dried off in the bathroom and as quickly as possible put on a knitted wool hat, cotton t-shirt, hooded cotton sweatshirt, cotton tracksuit bottoms/sweatpants, and socks. Participants were then covered in blankets on a bed in an adjacent bedroom with only their face exposed. This wrap was performed for 40 min. Room temperature ranged from 24ºC to 29ºC during the trials. This 60 min bath and wrap protocol is considered one round and was repeated twice per main experimental trial (Figure 1).

Upon completion of the second round, participants began the weight regain process and were prescribed to consume fluids (in L) to the equivalent to 150% of total body mass lost (in kg) [21] from Morning Day -1, and to consume 6 g/kg body mass of carbohydrate throughout the rest of the day.

For the FWB trial, only fresh tap water was used in the bath. For the SWB trial, Epsom salts (magnesium sulfate) were added to the bath with 160 L capacity at a concentration of 2 kg in 125 L of water (i.e. ~1.6% wt/vol). This quantity and type of salt was used in our previous work and was chosen based on our personal experiences of the practices of fighters making weight in combat sports, and was subsequently confirmed as approximating general practices of that participant cohort in exit questionnaires completed by the study participants [14].

Change in body mass, measured to the nearest 0.05 kg (model #63667; Soehnle, Germany), was the primary outcome measure. Body mass was measured in minimal clothing, i.e. lower body short underwear in the form of briefs or boxer briefs, at several time-points (Figure 1): (i) upon waking on the day prior to bathing (Morning Day -1), (ii) upon waking on the day of bathing (Morning Day 0), (iii) immediately prior to the first bath, (iv) immediately before the second bath, (v) immediately after the second wrap, and finally, (vi) upon waking on the day after bathing (Morning Day +1).

Urine osmolality was measured (Osmocheck Portable Osmometer; Vitech Scientific, UK) at the same time points except immediately before the second bath and wrap. Participants were defined as dehydrated using a criteria of urine osmolality of >700 mOsmol/kg [21].

Sample size calculation

The primary outcome was change in body mass as a consequence of the 2 h bath and wrap protocol. Therefore, a sample size calculation was performed (G*Power v.3.1) based on previous research demonstrating an effect of salt water to augment the magnitude of body mass lost during hot water immersion when compared to fresh water [15]. Using the body mass lost after 2 h of that 4 h immersion protocol, a time point analogous to the present work, and that being 0.98 ± 0.44 kg and 1.24 ± 0.80 kg for fresh water and salt water respectively, and an assumed correlation between conditions of 0.90, the required sample size to detect a difference between FWB and SWB at a Type I error rate (a) of 0.05 and a power (1-b) of 0.8 was $n = 26$. However, because these data are based on a higher salt concentration of ~3.5%, and given the absence of effect in our previous research using a salt concentration of 1.6% [14], *a priori* we planned an interim data analysis for the assessment of futility, and therefore discontinuation, after completion of one-third (n~8) of the required sample size. In the absence of any difference between FWB and SWB for change in body mass with $n = 8$ ($P = 0.867$ between trials, $d = 0.07$; data reported below), we discontinued recruitment at that time.

Statistical analysis

Statistical analysis and graphical representation were performed using GraphPad Prism v8.3 (GraphPad Software, Inc., USA). Normality of data was assessed with the Shapiro-Wilk normality test, for which all data passed. All data are presented as mean ± SD. A two way (condition x time) repeated measures analysis of variance (ANOVA) was used to assess responses to the interventions. When a main or interaction effect was observed, pairwise comparisons were performed with Bonferroni's correction for which multiplicity-adjusted P-values are reported. Paired t-tests were used to assess differences between trials for the quantity of boiling water added, and differences in body mass lost during bathing between this study and our previous study for the $n = 6$ participants common to both studies. The level of significance for all tests was set at $P < 0.05$. Standardized differences in the mean were used to assess magnitudes of effects between conditions. These were calculated using Cohen's d effect size and are interpreted using thresholds of < 0.2, ≥ 0.2, ≥ 0.5 and ≥ 0.8 for *trivial*, *small*, *moderate*, and *large*, respectively.

RESULTS

After starting each bath temperature at 37.8°C, the participant's self-adjustment of bathing temperature resulted in progressive increases in water temperature in both the 1st and 2nd baths (main effect of time, $P < 0.001$) (Figure 2A & 2C). Average water temperature in the 1st bath of each trial was 38.41 ± 0.31°C and 38.16 ± 0.31°C for FWB and SWB, respectively ($P = 0.135$), and in the 2nd bath of each trial was 38.48 ± 0.36°C and 38.64 ± 0.22°C for FWB and SWB, respectively ($P = 0.341$). Final water temperature in the 1st bath of each trial was 38.94 ± 0.70°C and 38.93 ± 0.63°C for FWB and SWB, respectively ($P = 0.972$), and in the 2nd bath of each trial was 39.14 ± 0.70°C and 39.59 ± 0.45°C for FWB and SWB, respectively ($P = 0.154$). No condition or interaction effects were observed for the effect of salt (Figure 2A & 2C). The volume of boiling kettle water added to each bath was 4.50 ± 1.96 L for FWB and 5.44 ± 1.12 L for SWB during the 1st bath of each trial ($P = 0.305$), and 4.69 ± 2.03 L for FWB and 5.81 ± 0.96 L for SWB during the 2nd bath of each trial ($P = 0.080$) (Figure 2B & 2D).

For change in body mass in absolute (kg) (Table 1) and relative (%initial body mass) (Figure 3) terms, a main effect of time ($P < 0.001$), but neither a main effect of condition, nor a condition*time interaction effect, was observed. Similarly, there was no difference between conditions for changes in urine osmolality at the various time points (Table 1).

Body mass losses induced by carbohydrate and fluid restriction were 2.14 ± 0.78 kg ($P < 0.001$; $d = 0.44$) and 2.08 ± 0.96 kg ($P < 0.001$; $d = 0.40$) in preparation for the FWB and SWB trials, respectively. Body mass losses induced by the hot bath protocols were 1.71 ± 0.70 kg ($P < 0.001$; $d = 0.37$) and 1.66 ± 0.78 kg ($P < 0.001$; $d = 0.34$) for the FWB and SWB protocols, respectively. FWB resulted in body mass loss of 0.76 ± 0.53 kg ($P = 0.005$;

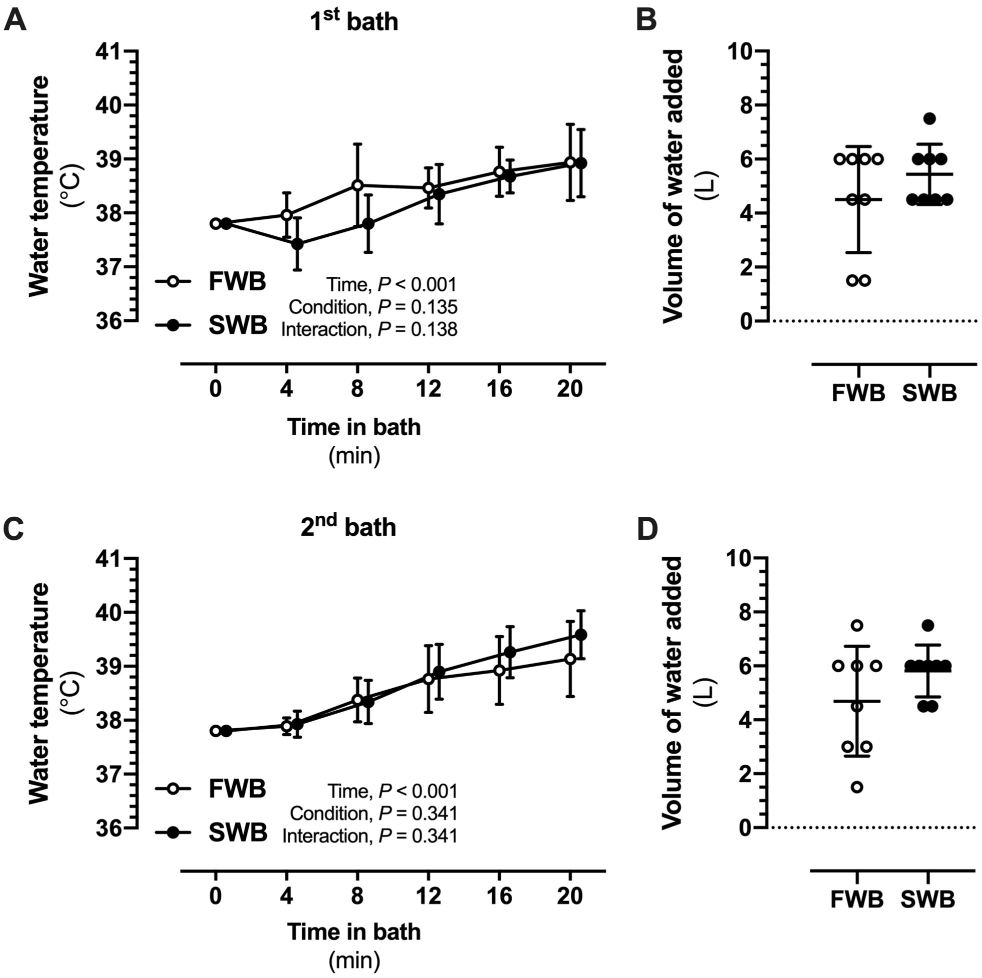

FIG. 2. Water temperatures measured at 4 min intervals during each bath (A, 1st bath; C, 2nd bath) during experimental trials of fresh (FWB) or salt water (SWB); and quantity of boiling kettle water added per bath (B, 1st bath; D, 2nd bath). White (FWB) and black (SWB) circles in panels B and D represent individual data points. Otherwise data are mean values with vertical bars representing SD.

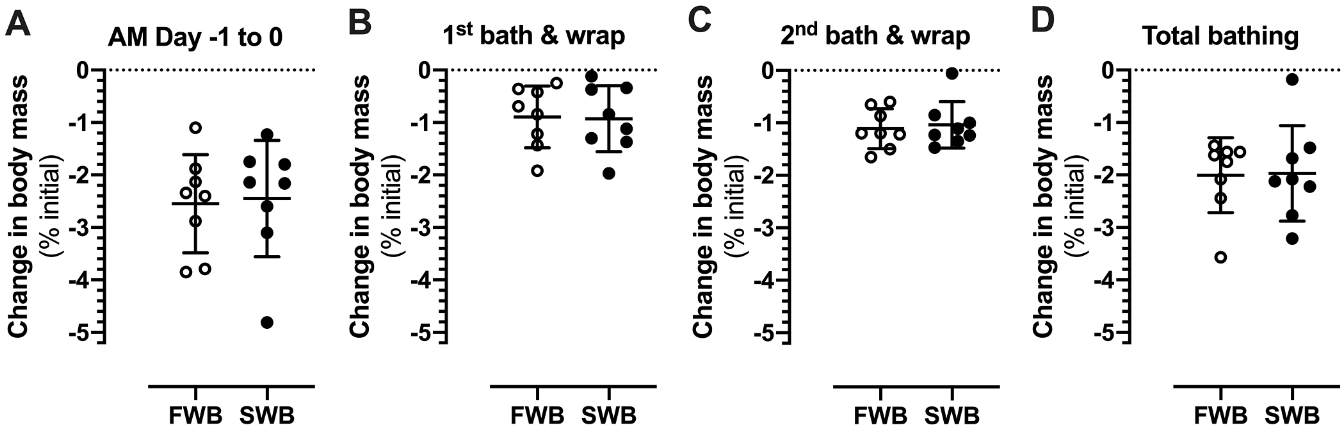

FIG. 3. Percentage changes in body mass (relative to baseline recorded on Morning Day -1) induced by diet and fluid restriction, and a hot bath protocol in fresh (FWB) or salt water (SWB) for (A) the period from Morning Day -1 to Morning Day 0, (B) the 60 min period comprising the first bath and wrap, (C) the 60 min period comprising the second bath and wrap, and (D) the 120 min period comprising both baths and wraps. White (FWB) and black (SWB) circles in each panel represent individual data points. Mean values are represented by the horizontal solid line with vertical bars representing SD for changes observed within each time period that is defined above each panel.

TABLE 1. Body mass (kg) and hydration status assessed by urine osmolality (mOsmol/kg) at time points during a rapid weight loss intervention featuring a hot bath protocol in fresh (FWB) or salt water (SWB).

	Morning Day -1	Morning Day 0	Before 1st bath	After 1st bath & wrap	After 2nd bath & wrap	Morning Day +1	*P* value
	Body mass (kg)						Time, P < 0.001
FWB	85.03 ± 4.87	83.31 ± 4.86	82.89 ± 4.83	82.13 ± 4.61	81.18 ± 4.40	84.75 ± 4.72	Condition, *P* = 0.919
SWB	84.94 ± 5.45	83.34 ± 4.98	82.86 ± 4.85	82.09 ± 5.01	81.21 ± 4.87	84.60 ± 5.04	Interaction, *P* = 0.953
Urine osmolality (mOsmol/kg)							Time, P = 0.001
FWB	718 ± 137	880 ± 137	856 ± 117		989 ± 126	909 ± 134	Condition, *P* = 0.333
SWB	709 ± 234	939 ± 121	897 ± 152		943 ± 90	954 ± 133	Interaction, *P* = 0.615

Data are presented as mean ± SD, n = 8.

d = 0.16) during the 1st bath and wrap, and 0.94 ± 0.35 kg (*P* = 0.001; *d* = 0.21) during the 2nd bath and wrap. SWB resulted in body mass loss of 0.77 ± 0.52 kg (*P* = 0.004; *d* = 0.16) during the 1st bath and wrap, and 0.88 ± 0.40 kg (*P* < 0.001; *d* = 0.18) during the 2nd bath and wrap.

Total body mass losses induced by the entire RWL protocol were 3.84 ± 0.74 kg (*P* < 0.001; *d* = 0.83) and 3.74 ± 0.70 kg (*P* < 0.001; *d* = 0.72) for the FWB and SWB protocols, respectively. These values represented losses of relative to initial body mass on Morning Day -1 of 4.55 ± 0.77% and 4.44 ± 0.66% for the FWB and SWB protocols, respectively (Figure 4A).

Weight regain was 3.57 ± 0.86 kg (*P* < 0.001; *d* = 0.78) and 3.39 ± 0.87 kg (*P* < 0.001; *d* = 0.89) during recovery from the FWB and SWB protocols, respectively (Figure 4B), resulting in a body mass deficit compared to Morning Day -1 of 0.28 ± 0.44 kg and 0.34 ± 0.89 kg, respectively (Figure 4C). At Morning Day +1, 6 (FWB trial) and 5 (SWB trial) participants were in a body mass deficit compared to Morning Day -1, and all participants, regardless

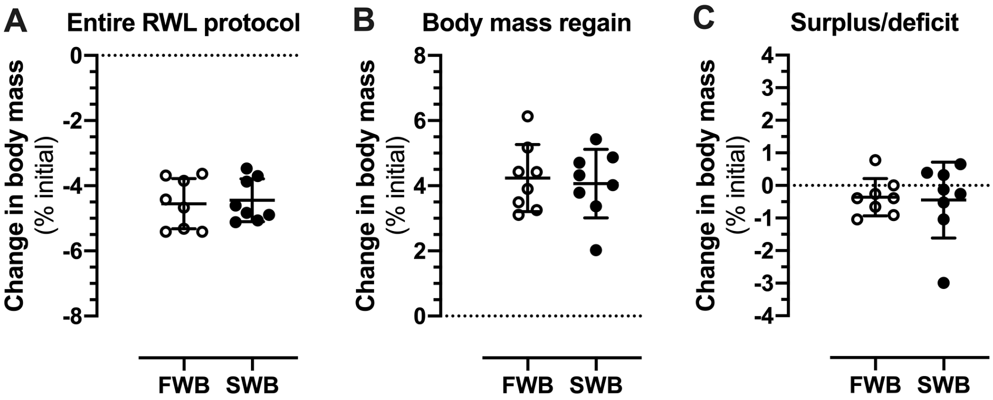

FIG. 4. Percentage changes in body mass (relative to baseline recorded on Morning Day -1) during (A) the entire rapid weight loss intervention featuring a hot bath protocol in FWB or SWB, (B) the period of weight regain prior to weigh-in on Morning Day +1, and (C) as a measure of total body mass deficit or surplus on Morning Day +1 compared to Morning Day -1. White (FWB) and black (SWB) circles in each panel represent individual data points. Mean values are represented by the horizontal solid line with vertical bars representing SD for changes observed within each time period that is defined above each panel.

of trial, were defined as dehydrated by having a urine osmolality >700 mOsmol/kg [21], both immediately after the 2nd bath and wrap, and at Morning Day +1.

Comparing the n = 6 participants common to the present study and our previous work [14], body mass lost during the bathing protocol using SWB was 1.57 ± 0.46 kg for bathing at 37.8ºC, and 1.98 ± 0.47 kg for the present study of self-adjusted maximum tolerable temperature of ~39.0ºC ($P = 0.152$; $d = 0.89$). Expressed as percentage of body mass prior to the 1st bath of each trial, this is equivalent to 2.07 ± 0.61% and 2.62 ± 0.62% for bathing at 37.8ºC and ~39.0ºC, respectively.

DISCUSSION

The present study demonstrates that the body mass lost when bathing in a hot bath of fresh water (FWB) is similar to bathing in a hot bath with ~1.6% Epsom salt added (SWB). This finding is consistent with our previous work using the same bathing protocol but performed at a fixed water temperature of 37.8ºC [14]. The present study extends that work by investigating body mass lost when the water temperature is self-adjusted to a fighter's own maximum tolerable temperature. While there was greater body mass lost in hotter water temperatures in those participants common to both studies, there was again no effect of adding salt on the magnitude of body mass lost compared to fresh water.

Investigating body mass loss when the water temperature is self-adjusted to a fighter's maximum tolerable temperature was undertaken as a means to extend the ecological validity of our previous hot bath study [14]. An exit questionnaire performed during that study revealed that the most obvious difference between that study design and protocols that fighters were currently practicing was the temperature of the water i.e. all but one participant found our bathing protocol at 37.8ºC to be colder than the hot water immersion that they usually employ, and all participants reported that in practice they increase the water temperature throughout each immersion. However, even at the increased water temperature of ~39.0ºC, there was still no difference observed on body mass lost between the FWB and SWB trials. This finding, combined with our previous work, suggests that an interaction effect between water temperature and salt concentration, i.e. that addition of salt produces greater loss of body mass or body water at higher water temperatures, does not exist in the hot bath protocol employed. This is unsurprising given that of the work that previously suggested an interaction effect between water temperature and salt concentration, one study was performed with an *n*-size of one participant [17], and the other employed a forearm model of water exposure under rubber or neoprene sleeves [19].

That said, the addition of salt during hot baths is common practice in MMA athletes [14], and there is some empirical evidence of the effect of adding salt to increase body mass lost during immersion in water [15–17]. Early work established that even in thermoneutral water, i.e. in the absence of sweating, immersion in a strong salt solution (either 11.5% or 20.0% salt as sodium chloride) produces passive fluid loss [17]. In water heated to 36/37ºC, addition of 5% sodium chloride allowed for higher sweat rates during 3 h of immersion when compared to fresh water, with the effect more pronounced at salt concentrations of 10% and 15% [16]. Lastly, during immersion in seawater compared to fresh water, ~32% greater body mass was lost in the former during 4 h of immersion at ~38ºC [15].

Given that seawater is ~3.5% salt, it may be that the concentration of salt in a hot bath should be at least 3.5% [15], or possibly greater [16, 19], if the aim is to augment the rate of passive fluid loss that would otherwise occur in fresh water. Despite these indications, we employed a salt concentration of only ~1.6% wt/vol magnesium sulfate, but this quantity and type of salt was chosen for its ecological validity based on data from exit questionnaires in our previous work [14].

Future work should certainly investigate higher concentrations of salt in order to produce a larger osmotic gradient between the bath water and body fluids. The suggested mechanisms for how the addition of salt influences the loss of body mass during immersion are (i) that salt water serves to remove an inhibitory influence on the decline in sweat rate that usually occurs with prolonged immersion in fresh water, and/or (ii) that during immersion in salt water, the osmotic pressure difference between the immersion medium and body fluids results in greater fluid loss compared to fresh water [15–20]. However, in studies where an additive effect of salt has been observed, these have been 3 to 4 h immersions [15, 16], in contrast to the only 40 min of immersion time across the 2 h bath and wrap protocol that we employed. Moreover, whether the type of salt (i.e. seawater versus added Epsom salt) would make any difference to the outcome remains to be explored, but is unlikely. In previous work, when the osmotic gradient was produced by either sodium chloride, potassium chloride or cane sugar, the diffusion of water through the skin was similar in all conditions [19].

Absent an effect of the addition of salt under the conditions employed in our two studies, because there were six participants common to both studies, it was possible to explore the effect of self-adjusting the water temperature on body mass loss. Expressed as percentage of body mass prior to the respective 1st bath, the magnitude of loss was 2.07 ± 0.61% for the previous study at a water temperature of 37.8ºC, and 2.62 ± 0.62% for the present study at ~39.0ºC. While this difference was not statistically significant ($P = 0.152$), perhaps given the small n-size, the magnitude of the effect size was '*large*' ($d = 0.89$), and in practical terms translates to an extra ~410 g of body mass lost. As part of the process of making weight in weight category sports, this is a practically-meaningful amount of weight loss and speaks to the importance of water temperature in the hot bath process, but should be kept within safe limits, which remain to be defined. For illustration, water temperatures rarely exceeded 40ºC across all participants and baths, and previous immersion studies have typically used temperatures of ~38/39ºC [14–16, 22–25], but water temperatures of ~41ºC acutely [18], and ~40ºC repeated daily for six days [26], have also been employed without adverse effects being reported.

Despite the greater body mass loss with the higher water temperature in the present study, consistent with our previous work, there was a greater loss of body mass by the 24 h of restriction of carbohydrate, fibre, and fluid intake (FWB, -2.54 ± 0.93%; SWB -2.45 ± 1.11%), than from either bathing protocol (FWB, -2.00 ± 0.71%; SWB, -1.97 ± 0.91%). The loss of body mass with 24 h of such restriction is attributed to dehydration, short-duration glycogen depletion, and emptying of the intestinal contents [2], and like the present study is typically ~2–3% of body mass [2, 14, 27]. Therefore, while gradual weight loss using an appropriate calorie deficit is central to a weight loss strategy lasting several weeks or months [2], for the RWL period prior to weigh-in, acute (< 48 h) dietary manipulation (carbohydrate, fibre, and fluid intake) should be considered prior to employing aggressive heat-stimulated dehydration strategies, particularly if the desired weight loss is less than ~3% of body mass.

After the second wrap, a time point chosen to be typical of a weigh-in time for MMA athletes, total body mass lost including the 24 h restriction and 2 h hot bath protocol was ~4.5%. At this timepoint, all participants were classified as dehydrated based on a urine osmolality of >700 mOsmol/kg [21]. This finding is consistent with typical methods of RWL resulting in 100% of MMA athletes being dehydrated to various degrees at an official weigh-in [3, 28]. Body mass and hydration assessment performed on Morning Day +1 represents an ~20 hour recovery period after completing the second bath and wrap, and a body mass deficit and dehydration were observed at this timepoint. However, in practice the time from weigh-in until official competition in professional MMA is usually longer i.e. approximately 30 to 36 h. Even with a long time period for rehydration, the majority of MMA athletes remain dehydrated up to 2 h before competition [3, 28]. Therefore, regain of body mass alone is potentially not a good indicator of returning to euhydration, and indeed there remains some debate about the assessment of hydration status by spot analysis with urine measures [29].

The small sample size ($n = 8$) employed may be considered a limitation of the present study. However, this sample size was finalised based on a pre-planned interim data analysis for the primary outcome of change in body mass during the 2 h bath and wrap protocol. The small sample size may result in assessment of the secondary outcomes by ANOVA being underpowered, and thereby increase the likelihood of a type II error (i.e. false negative) for these outcomes. Another limitation of this study may be the heterogeneity in the experience of the participants with RWL practices. All participants had prior experience with making weight for competition and the use of hot baths in that process, but during either our recruitment or analysis, we did not account for the number of lifetime exposures to these practices. While speculative, it may be that the response to such practices changes over time, but with participants acting as their own control in this crossover design, we do not anticipate that this aspect had a meaningful impact on the results. Lastly, the magnitude of body mass lost during the entire RWL process averaged ~4.5% of body mass, whereas in practice losses of ~5% to 10% are typical in these athletes in the week prior to competition [3–9]. Therefore, whether there would be a differential effect of salt water when bathing has been preceded by RWL of greater magnitude cannot be excluded as a possibility.

CONCLUSIONS

In summary, hot baths are an effective method of RWL to produce a loss of ~2.0% body mass during 2 h of bathing and wrapping. When fighters self-adjusted the water temperature in the bath, temperatures were ~39.0°C. However, using this protocol, the total amount of body mass lost during a hot bath in water supplemented with ~1.6% Epsom salt was similar to a hot bath performed in fresh water. Future research should explore bathing in higher concentrations of salt, which likely need to be >3.5% in order to produce a sufficient osmotic gradient between the bath water and body fluids.

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Conflict of interest

No conflict of interest, financial or otherwise, is declared by the authors.

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