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Original Article

Rapid weight loss negatively effects salivary IgA before competition in elite powerlifters

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Abstract
Problem Statement: Little is known about whether rapid weight loss (RWL) through fluid manipulation influences markers of hydration, body compartment water and salivary immune response before or after a full powerlifting competition when compared to competitors that did not use any methods of weight reduction. **Purpose:** The purpose of this study was to determine if RWL before competition negatively impacted markers of hydration and salivary immune function and whether those markers were altered by competition compared to those that did not undergo RWL. **Approach**: On the day of competition 21 (14 male, 7 female) participants underwent anthropometry for intra-cellular (ICW), extra-cellular (ECW), and total body water (TBW) and then provided urine and saliva samples immediately prior to completing a full powerlifting competition of squat, bench press, and dead lift. Urine was used to measure urine specific gravity (USG) and saliva was used to determine salivary immunoglobulin A (sIgA). Measures were repeated following competition. Participants were analyzed as non-body weight manipulation (HH, -0.41±0.17 % body mass, n=8) or RWL fluid manipulation (DH, -3.32±0.76% body mass, n=13) with significance being set at $p \leq 0.05$. **Results**: There was a significant difference in the amount of body mass lost between participants in DH (reduced body mass by 3.1-4.7% [1.74 - 4.36kg] over a 3-day period) compared to HH (<0.5% [≤0.51kgs]) over the same time (p<0.001). There were no differences between groups in USG at either time point. DH presented with significantly lower sIgA (p=0.003), ICW (p=0.004), and TBW (p=0.009) compared to HH. Both groups significantly increased sIgA (p=0.042), ICW (p<0.001), and TBW (p=0.001) pre-to-post-competition with DH having significantly higher increases in ICW (p=0.008) and TBW (p=0.018) compared to HH. sIgA (p=0.020) and ICW (p=0.039) differences were maintained post competition with DH having significantly lower values. Both groups significantly increased sIgA secretion rate pre-to post-competition (p=0.018) but with no difference between groups at either time point. **Conclusions**: RWL appears to suppress sIgA and cause compartment loss of water in elite powerlifters. Competitors presenting with indicators of body and compartmental dehydration increased hydration levels over the course of a full competition with *ad libitum* consumption but should be cautious of inducing serious dehydration which has negative health and performance implications.
Key Words: Body Water, Dehydration, Immunoglobulin, Intra-cellular water, Urine specific gravity

Introduction

In weight-controlled sports, athletes often reduce body mass to compete in the lowest category possible to gain a perceived competitive advantage (Artioli et al, 2010; Artioli et al, 2016; Coufalova et al, 2013). One common method for reducing body mass for competition is through manipulating body water (Coufalova et al, 2013; Gordon, Souglis, Andronikos, 2021; Park et al, 2019). However, when examining weight-controlled sports, previous studies did not always differentiate between rapid weight loss (RWL) from water manipulation versus caloric restriction (Judelson et al, 2007b). Dehydration can negatively affect performance in aerobic (Deshayes et al, 2020) and resistance training (Judelson et al, 2007a & b), but few studies exist that offer external validity to the resistance training (Judelson et al, 2007a), with the majority of the literature examining anaerobic biking or jumping power output or being limited by a learning effect in novice resistance trained individuals (Judelson et al, 2007b). The use of body mass resisted tests (Cheuvront et al, 2006; Gutierrez et al, 2003) complicates the interpretation of results as dehydration reduces body mass and may mask decreases in performance. Few studies have examined resistance training with trained power athletes, but those that have indicate that power athletes have a greater inability to maintain ≥50% peak isokinetic torque after ~3% hypohydration when compared to endurance athletes (Caterisano et al, 1988). Most studies to date have utilized isometric and isokinetic activities but there is a dearth of evidence regarding the effects of dehydration on isotonic resistance exercise. Further, little is known about the hydration status of weight-controlled athletes outside of combat and grappling sports during competition. If strength athletes undertake similar methods of RWL, evidence indicates that trained individuals undergoing passive dehydration are more likely to experience performance decrements than untrained or actively dehydrating individuals (Savoie et al, 2015). The magnitude

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of weight reduction through fluid manipulation appears to have an effect on performance decrements above 2.8% body mass (%bm) lost (Deshayes et al, 2020). Resistance trained athletes may be particularly susceptible to changes in hydration due to the accretion of fast-twitch skeletal muscle. Fast-twitch muscle appears to play an important role in cellular hydration (Riberio et al, 2014) and cellular swelling, a proposed mechanism of hypertrophy, has been suggested to be maximized by training that improves glycolysis (Schoenfeld, 2013). RWL appears to exacerbate skeletal muscle damage (Roklicer et al, 2020) which may further inhibit resistance exercise performance and create health concerns with high intensity exercise. It has been postulated that changes in intra- and extra-cellular water levels may have negative renal and cardiovascular health outcomes (Lukaski et al, 2019; Volpe, Poule & Bland, 2009). At dehydration levels observed to negatively affect performance (2-3%bm) there is also an observed increase in cardiovascular strain through hypovolemia, tachycardia, decreased venous return, and decreased stroke volume (Armstrong et al, 1997; Maughan, 2003) which makes monitoring these compartmental changes in body fluids an important avenue of investigation. Indeed, grappling and combat sports have taken interest in the manipulation of body water to reach a weight class with some suggesting preventative measures be taken to avoid these physical (Artioli et al, 2010; Artioli et al, 2016; Coufalova et al, 2013; Park et al, 2019; Utter, 2001) and other psychological (Gordon, Souglis & Andronikos, 2021) health issues noted in these athletes. Recently, Augustovicova, et al, (2021) noted that proximity of weigh-in to competition appears to deepen unhealthy weight restriction. While the karate competition studied by Augustovicova, et al, (2021) utilized immediate weigh-ins before competition, powerlifting competitions have a two hour window before first attempt of squat in the weight class. This scheduling is similar to grappling which has documented health concerns with RWL techniques (Artioli et al, 2010; Artioli et al, 2016). Therefore, similar health concerns may be present in powerlifting competitions.

Other health issues may arise from RWL and dehydration; some studies have examined the role of dehydration on systemic perturbations as a result of exercise that may lead to an increased incidence of upper respiratory tract infections (URTI) through changes in mucosal immunity (Fortes et al, 2012; Ide et al, 2019; Walsh & Oliver, 2016). URTI symptoms have negative effects on health and exercise performance (Nieman et al, 2004). Exercise has long been demonstrated to alter immunity (Walsh & Oliver, 2016); however, whether it improves, inhibits, or has little practical significance is still largely disputed. In recent years contradictory or inconclusive evidence has been shown to complicate the relationship between aerobic exercise and immune function (Walsh & Oliver, 2016), much of which is likely due to differing durations and intensities of work in addition to the initial health status of the participants. One of the most commonly investigated components of exercise and hydration modulated immunity is salivary immunoglobulin A (sIgA) which is an antibody secreted through mucosal lining and is seen as the front line of defense once pathogens have made their way to these surfaces (Moghetti & Lavoie, 1998). The degree to which intensity, duration, mode of exercise, and hydration directly influence these changes in immune status is lacking agreement (Allgrove et al, 2008). Combat sports are some of the most extensively investigated, such as Judo (Chishaki et al, 2013), Brazilian Jiu Jitsu (Ide et al, 2019), and Taekwondo (Tsai 2011a & b). A myriad of individual and team events in labs and fields such as cycling (Fortes et al, 2012), tennis (Novas, Rowbottom & Jenkins, 2003), Olympic Weightlifting (Tsai et al, 2012), and rugby (Trochimiak & Hubner-Wozniak, 2012) have also been studied to a degree, but also incorporate variable intensities with none examining competitive maximal resistance exercise or similar weight loss or dehydration procedures on sIgA. This has led to disagreement in how high intensity exercise affects high level athletes compared to lower level athletes or general population (Gleeson, 2000; Walsh & Oliver 2016) and generally made reports hard to interpret due to the variable nature of intensity during team sport or sport that has a high degree of intermittency (Ide et al, 2019) and whether prolonged or transient changes to hydration cause negative health effects.

Reports of changes to circulating immune cells and mucosal antibodies following dehydration due to exercise versus planned restriction of fluids are mixed (Chishaki et al, 2013; Hiraoka et al, 2019; Ide et al, 2019; Tsai et al, 2011a; Tsai et al, 2011b; Walsh & Oliver, 2016). Dehydration resulting from a practice session may either increase circulating immune cells and antibodies (Ide et al, 2019) or decrease them (Chishaki et al, 2013). Both Ide et al. (2019) and Chishaki et al. (2013) utilized high intensity grappling practice for their studies (Brazilian Jiu Jitsu and Judo, respectively), but there was a notable difference in the duration of activity with Chishaki et al. examining a 2.5 hour practice compared to the roughly 30 minutes of Ide et al. Purposeful restrictive RWL of less than 3%bm (Tsai et al, 2011a; Tsai et al, 2011b) or more severe 3-5%bm lost (Hiraoka et al, 2019; Walsh & Oliver, 2016) leading into competition both significantly decreased sIgA and increased symptoms of URTI. It is unclear whether the sustained nature of RWL over a relatively longer timespan compared to the transient dehydration of a practice session delineates the severity of immune and health impact. These differences may parallel changes seen before competition when comparing RWL versus no weight loss because of practical implications of competition. Consider morning weigh-ins, where a group that did not engage in RWL may still have some transient dehydration from the night's sleep. Outside combat sports, little evidence exists to the relationship between resistance exercise and immune function (Da Canha Neves et al, 2009; Nieman et al, 2004; Roschel et al, 2011; Tsai et al, 2012) which have displayed mixed results with no studies examining the stress of maximal resistance exercise on immune function. Roschel et al. (2011) utilized moderate intensity (5 sets of 10 repetitions at 70% 1-repetition max [1-RM]) squats on a vibration platform and found no change in sIgA within recreationally trained males, whereas Nieman et al. (2004) saw a decrease in sIgA pre- to post-exercise in resistance-trained males after 2 hours (4 sets of 10 resistance exercises with 2-3 minutes rest between sets) of resistance exercise. This appears to indicate that duration of training is most influential in determining movement of sIgA, but Da Cunha Neves et al. (2009) displayed an increase in sIgA after 6 resistance exercises of either 2 sets of 13 reps at 50% 1-RM and 2 sets of 8 reps at 80% 1-RM in older women. This may imply that age or sex also has an influence on the immune response to resistance training, further complicating matters. However, none of those studies examined the role of RWL on salivary immunity in resistance exercise, leaving the intersection of these activities uncertain and their implications for competition unclear. While some studies have examined secretory immune levels leading to and following competition (Tsai et al, 2012), none to our knowledge have examined the response to competition itself. Tsai et al. (2011a & b) examined RWL through fluid restriction on salivary immune and hydration markers and reported a suppressing effect leading into Taekwondo competition. Resistance exercise offers a unique anaerobic challenge to the body that breaks down tissue and stresses the joints in a way not seen in all sporting events (Moghetti et al, 2016). Competitive lifting specifically provides a near-maximal to supramaximal intensity challenge to the body. Some studies suggest these and similar tissue perturbations make it more likely for subsequent changes in immune concentrations following exercise (Chishaki et al, 2013; Ide et al, 2019). These challenges to the immune system may increase the likelihood of illness, which may decrease performance or prevent competition all together.

Therefore, this study aims to determine if RWL through dehydration negatively influences compartmental hydration and sIgA levels and if there is a differential response between elite powerlifters before and following competition who underwent RWL versus those that did not.

Methods

Participants enrolled in the study through online requests. Anthropometrics were assessed on-site following a successful weigh in. Participants that did not successfully make weight were not included in the study. At this point, participants provided urine and saliva samples. Participants competed in a full powerlifting competition. A full competition is comprised of up to three attempts of the squat, bench press, and dead lift in that order. Participants that did not complete the full meet by withdrawing before receiving a meet total or by missing all attempts in one or more lift categories were not included in the study. Immediately following their final lift attempt, participants reported back to the investigators to provide another saliva and urine sample and underwent another round of anthropometric evaluation. Participants had refrained from eating food for at least 20 minutes prior to giving either saliva sample, but were not redistricted on food and fluid intake during the competition otherwise.

Participants

Twenty-one male (n=14) and female (n=7) national level powerlifting competitors were recruited for the study that was conducted during the 2015 USA Powerlifting Raw Nationals competition. All participants placed in the top five in their respective age group weight classes. The experimental procedures, benefits, and risks were explained to all participants with written informed consent obtained before testing as approved by the author’s Institutional Review Board.

Procedures

URTI Questionnaires

Before arriving to the venue for competition, participants were asked to complete the short form Wisconsin upper respiratory symptom survey 21 (WURSS-21) (Barrett et al, 2009) at the same time each week over the 4 weeks preceding the event and another on the day of the event to determine if the presence of illness may confound sIgA results (Marcotte & Lavoie, 1998). URTI symptoms were not clinically verified.

Anthropometry, Body Composition Assessment, and Hydration

Height was measured using a stadiometer (402LB, Health-o-meter, Toledo, OH, USA) and recorded to the nearest 0.5cm. Weight (to 0.1kg), body composition (to 0.1%), intra-cellular water (ICW), extra-cellular water (ECW), and total body water (TBW) (all to 0.1kg) was determined using InBody 520 Body Composition Analyzer (Biospace, Inc., Beverly Hills, CA). This segmental bioelectrical impedance (SBIA) unit takes fifteen impedance measurements by using three different frequencies (5kHz, 50kHz, 500KHz) at each of the five segments (right arm, left arm, trunk, right leg, left leg). Participants completed a survey prior to competition indicating the total amount of weight lost, the duration it took them to do so, and the method by which they accomplished it. This was used to separate participants into two groups: One that performed RWL through fluid restriction (DH) wherein they reduced body mass by ≥3% within 3 days of competition and another that did not (HH) and had < 1% reduction of body mass within 3 days of competition which was treated as a control.

Saliva Collection

Following a successful weigh-in, and before ingesting any food or drink, saliva samples were obtained. Briefly, participants were given a sterile 15 milliliter conical tube (Corning, Inc.; Corning, NY) and instructed to passively drool into it for 5 minutes. Once time had elapsed, participants capped the tube and gave it to the investigator. Saliva tubes were immediately frozen at -20^{o}c until future analysis.

Urine Collection

Participants provided a urine sample at the same time periods as the saliva sampling to be used for urine specific gravity (USG) which was determined using a refractometer urine pen (Atago PEN-Wrestling refractometer, Atago USA, Inc., Bellevue, WA). Dehydration was considered USG ≥1.016 (Owen et al, 2019; Walsh & Oliver, 2016).

Salivary immunoglobulin analysis

Analysis of sIgA were completed via commercially available enzyme-linked immunosorbent assay (ELISA) kits (Salimetrics, Carlsbad, CA) in triplicate. The assay was performed according to the manufacturer's instructions. Intra-assay coefficient of variation was 4.2%.

Statistical Analysis

Data were analyzed by SPSS v23 (SPSS, Chicago, IL, USA). A 2 x 2 (time x condition) Analysis of variance (ANOVA) with repeated measures was carried out to determine differences. Where differences were found, univariate ANOVA and paired t-tests were performed to determine if differences existed pre- to post-competition. Statistical significance was set at the $p \leq 0.05$ level. *A priori* power analysis (G*Power v3.1.9.7, Germany) indicated a t-test with two n= 8 groups would yield a g*power value ≥0.80.

Results

Participants

Participant demographic information presented in table 1 (mean±SD).

URTI questionnaire

Participants reported no incidence of URTI symptoms for any of the twenty one questions in the weekly WURSS-21 reports or on the day of competition (all $p>0.05$).

Hydration

There was a significant difference in the amount of body mass lost between participants in DH (reduced body mass by 3.1-4.7% [1.74 - 4.36kg] over a 3 day period) compared to HH (<0.5% [≤0.51kgs]) over the same time [$F(1,19)=54.777$, $p<0.001$, $\eta p^2=0.742$] (Table 1). Both groups gained body mass pre-to-post-competition but were not significantly different in that amount ($p>0.05$).

ICW, ECW, and TBW were not significantly different between HH and DH pre-competition ($p > 0.05$). However, after covarying for body mass and height due to the range of weight classes included in the study (Tsai et al, 2011a), significant differences were observed between groups pre-competition in ICW [$F(1,17)=11.241$, $p=0.004$, $\eta p^2=0.398$] and TBW [$F(1,17)=8.557$, $p=0.009$, $\eta p^2=0.335$] with DH displaying lower masses of compartment and total water (Figure 1a and Figure 1b). Both HH and DH demonstrated significant increases in ICW [$F(1,7)=51.081$, $p<0.001$, $\eta p^2=0.879$] and TBW [$F(1,7)=27.485$, $p=0.001$, $\eta p^2=0.797$] pre-to post competition with DH showing greater increases in ICW [$F(1,7)=13.218$, $p=0.008$, $\eta p^2=0.654$] and TBW [$F(1,7)=9.429$, $p=0.018$, $\eta p^2=0.574$] compared to HH. ICW, ECW, and TBW were not significantly different between HH and DH post-competition ($p > 0.05$) until covarying for body mass and height which displayed significant differences for ICW [$F(1,17)=5.002$, $p=0.039$, $\eta p^2=0.227$] but not TBW [$F(1,17)=3.125$, $p=0.095$, $\eta p^2=0.155$]. Raw ICW and TBW values demonstrated a significant difference in the percent change pre- to post-competition between groups [$F(1,19)=19.483$, $p<0.001$, $\eta p^2=0.506$; $F(1,19)=16.026$, p=0.001, $\eta p^2=0.458$, respectively] with DH increasing compartmental water more than HH (Table 2).

USG saw no significant time or group effects (both $p > 0.05$; Figure 2). There was a significant time effect on salivary volume and flow rate [$F(1,7)=7.355$, $p=0.030$, $\eta p^2=0.512$] revealing a significant increase in volume and flow of DH pre-to-post competition ($p = 0.001$). HH did not display a significant increase pre- to post-competition ($p > 0.05$) and there were not significant differences between groups pre- or post-competition ($p > 0.05$).

Table 1. Participant Descriptive Data

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	DH (n = 13; 10M, 3F)	HH (n = 8; 4M, 4F)
Age (years)	25.69± 3.84	27.75± 3.92
Height (cm)	173.37±6.8	169.17±10.88
Weight (kg)	79.30±12.02	77.89±15.50
Body fat (%)	15.62±5.25	17.19±6.01
Years training	8.46±2.89	7.12±3.06
Body mass lost pre-comp (%)	-3.32±0.71*	-0.41±0.17
Body mass lost pre-comp (kg)	-2.67±0.88*	-0.32±0.15

Table 1: Mean±SD *Significant group differences in body mass lost in the three days prior to competition. P<0.001.

Table 2. Hydration and sIgA

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	DH (n = 13; 10M, 3F)	HH (n = 8; 4M, 4F)
USG (pre/post)	1.019±0.005/1.013±0.006	1.015±0.009/1.008±0.011
sVol (mL pre/post)	2.354±1.13/4.048±1.74*	2.099±1.01/2.835±0.683
sFlow (mL/min pre/post)	0.479±0.228/0.810±0.348*	0.419±0.203/0.567±0.137
ICW (kg pre/post)	34.57±6.59/36.18±6.75	36.54±8.02/37.05±8.10
ECW (kg pre/post)	20.56±3.78/20.98±3.95	21.19±4.23/21.27±4.27
TBW (kg pre/post)	55.13±10.34/57.16±10.66	57.73±12.23/58.32±12.37
sIgA (µg/mL pre/post)	280.98±21.85/292.75±19.81	310.41±14.86/314.29±17.22
Secretion rate sIgA (µg/min pre/post)	131.49±62.66/237.22±101.05*	128.83±59.01/168.05±38.50*

Table 2: Mean±SD *Significant differences pre-to-post competition p<0.05.

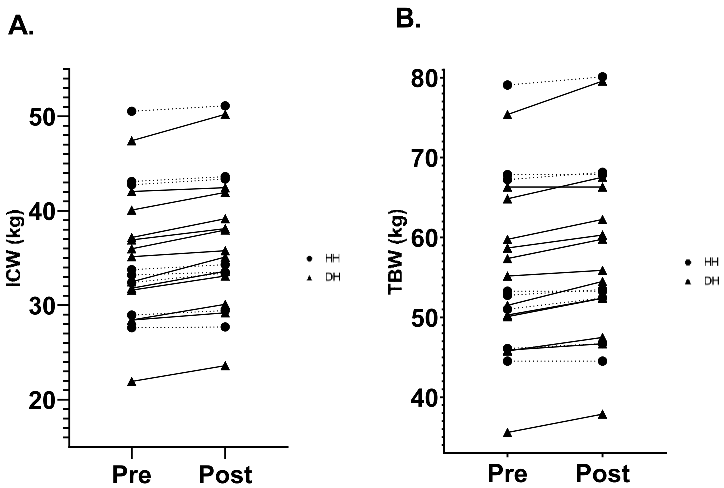

Figure 1: Raw compartment water masses pre-post competition. Figure 1a Intracellular water. Figure 1b Total body water. *Significant difference between groups in weight and height adjusted values p≤0.05.

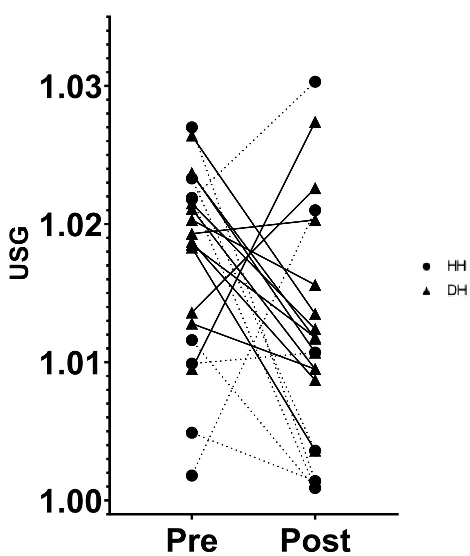

Figure 2: Urine specific gravity pre to post competition. No significant differences between groups p>0.05.

Salivary IgA

The concentration of sIgA was expressed as absolute concentration of sIgA (µg/mL) and secretion rate of sIgA (µg/min). Secretion rate of sIgA (µg/min) was calculated by multiplying the absolute sIgA concentration (µg/mL) by the saliva flow rate (mL/min), with saliva flow rate being calculated by dividing the total volume of saliva obtained in each sample (mL) by the time taken to produce each sample (5 min).

There were significant differences between groups in absolute sIgA pre-competition [$F(1,19)=11.205$, $p=0.003$, $\eta p^2=0.371$] and post competition [$F(1,19)=6.428$, $p=0.020$, $\eta p^2=0.253$] with the HH group presenting higher values at both times (Figure 3) but not in sIgA secretion rate at either time point (Table 2). There was a significant increase in sIgA [$F(1,7)=6.140$, $p=0.042$, $\eta p^2=0.467$] and sIgA secretion rate between pre- and post-competition regardless of group [$F(1,7)=9.414$, $p=0.018$, $\eta p^2=0.574$]. The percent change pre- to post-competition was significant between groups in absolute sIgA [$F(1,19)=6.757$, $p=0.018$, $\eta p^2=0.262$] but not secretion rate [$F(1,19)=1.818$, $p=0.193$, $\eta p^2=0.087$].

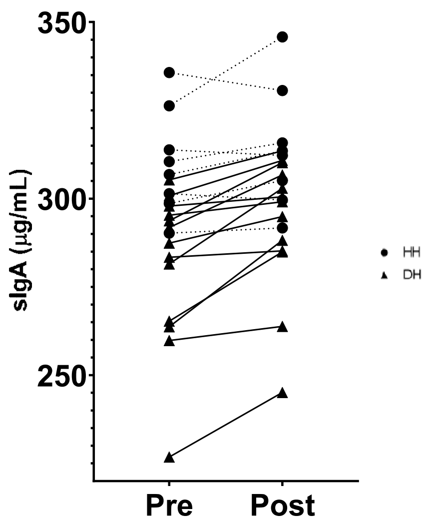

Figure 3: Salivary IgA pre to post competition.* Significant difference between groups pre and post competition p<0.05.

Discussion

This study is the first to directly measure the changes in sIgA concentration and secretion surrounding a full powerlifting competition in elite competitors. As well, this study represents the first endeavor to quantify changes to compartmental body water and hydration markers in these competitive athletes. The primary findings of this study were that absolute sIgA were significantly lower in the DH group entering and following competition with both groups increasing the amount of sIgA in response to competition. However, there was no significant difference in secretion rate before or following competition between groups, but was a significant difference in the percent change in DH compared to HH. Additionally, while there were no significant differences in USG and saliva volume and flow rate between participants that underwent RWL through fluid restriction and those that did not, there were significant differences in adjusted body compartment water content and absolute percent change to ICW and TBW. This study also observed that athletes entering competition after engaging in RWL improved measures of hydration over the course of competition.

This study observed athletes that undertook RWL to present with lower sIgA concentrations than those that did not. These findings agree with some (Tsai et al, 2011a & b) but not all (Hiraoka et al, 2019) studies that examined RWL before competition. While these studies reported that athletes underwent fluid restriction two (Tsai et al, 2011a & b) reported absolute body mass changes only making direct comparisons difficult. Hiroaki et al. (2019) reported similar findings to ours with less than 5% reduction in body mass did not significantly affect sIgA secretion rate compared to a group that did not undergo RWL, but did not observe a decrease in sIgA concentration compared to those not undertaking RWL. Additionally, no study examined competition day and instead recorded the day before or following competition. This is the first study to demonstrate the rise in sIgA seen in both DH and HH following competition. Studies examining acute resistance exercise and sIgA secretion are lacking and mixed, finding either no change (Roschel et al, 2011), a decrease (Nieman et al, 2004), or an increase (De Cunha Neves et al, 2009). It should be noted that across these studies there were vastly different experimental approaches ranging from a single resistance exercise to 2 hours of exhaustive training using 10 resistance exercises, these studies employed intensities ranging from 50-80% 1RM. As well, the populations were varied utilizing recreationally trained young adult men to physically independent elderly women. As this is the first study to identify changes to sIgA following maximal resistance exercise conclusions cannot be drawn at this point.

We observed significant decreases in body mass and height-controlled (Silva et al, 2019) ICW and TBW pre-competition with only ICW differences maintained post competition. These observed changes are in line with other studies examining RWL through exercise with fluid restriction (Mora-Rodriguez et al, 2015; Owen et al, 2019; Sanders, Noakes & Dennis, 1999). The decrease in ICW appears to be the result of compartment water redistribution following dehydration wherein ECW compartments decrease and osmotic pressure increases prompting ICW shifts to maintain the ECW levels (Mora-Rodriguez et al, 2015; Sanders, Noakes & Dennis, 1999). Our population may have been particularly susceptible to ICW water changes due to the presumably high proportion of fast-twitch fibers which have profound glycolytic potential. Both resistance exercise (Riberio et al, 2014) and glycogen storage (Shiose et al, 2016) increase ICW and likely exert a summation effect as part of cellular swelling adaptations to resistance training (Schoenfeld, 2013). TBW calculated as the sum of ICW and ECW would be expected to change whenever large shifts in either or both of the two component areas occur. While some RWL studies have observed a decrease in ECW (Relijic, Hassler & Freidmann-Bette, 2013) our study did not. This may be due to the larger decrease in body mass (5.6% vs 3.3%) over a longer time period (5 vs 3 days) observed by Relijic et al. (2013) which left inadequate ICW stores to compensate for the decrease in ECW compartment. However, our study did observe increases in ECW pre-to-post-competition in both groups (DH 2.01% vs HH 0.35%; $p = 0.090$).

Our study found USG readings that were in-line with studies examining dehydrated groups (Fortes et al, 2012; Owen et al, 2019; Utter, 2001). Recent studies have suggested that USG and saliva flow rate may be have the diagnostic accuracy for assessing ICW dehydration (De Cunha Neves et al, 2009). While DH met the criteria for USG dehydration threshold (>1.016) (Owen et al, 2019) and HH did not, we failed to observe significant differences between groups pre-competition. This may be explained by a practical approach to competition. Weight class qualification was held in the morning between 8:00-10:00 and neither group consumed large volumes of fluid or food before weigh-ins. This left half the participants in HH dehydrated (according to USG) from the night before, compared to more than three-fourths of participants in DH. (DH 78% USG≥1.016; HH 50% USG≥1.016).

Due to the nature of collecting field data our study is not without limitations. An ongoing issue with hydration research is the lack of uniformity in methodology and reporting. Indeed, some studies use %bm, while others report specific values from USG, plasma oSm, urine oSm, and others (Chishaki et al, 2013; Judelson et al, 2007a; Owen et al, 2019; Relijic Hassler & Freidmann-Bette, 2013; Sommerfield et al, 2016; Utter 2001; Volpe, Poule & Bland, 2009). We chose to use a combination of these (%bm, USG, and SBIA) that are the least costly and most likely to be applied by practitioners, making their findings more transferrable than blood based and invasive testing. USG and %bm is commonly used in NCAA wrestling certification weight (Utter 2001). Multi-frequency and compartmental water measurements are the more expensive of these measurements, but still more accessible than the gold standards of deuterium or bromide dilution (Riberio et al, 2014) which may suffer from assumptions of inter-individuals differences such as body composition. Skeletal muscle mass has been specifically identified as a compartment that differs in water content greatly between individuals (Lukaski et al, 2019) and this compartment may change with resistance training (Riberio et al, 2014; Schoenfeld 2013). However, it should be noted that while some measures like USG are widely utilized and accepted within field testing there are still concerns regarding their relatability to actual hydration (Sommerfield et al, 2016; Zubac et al, 2018). While SBIA presents some problems, recent reports have issued direction that the differences are not so great as to signal its disuse for data collection in healthy populations (Ward 2019) and the sensitivity may only be an issue for clinical groups (Lukaski et al, 2019). The cost factor of multi-frequency BIA may still be a limiting factor for practitioners so the use of single frequency bioelectrical impedance vector analysis may be a more useful approach to this problem (Silva et al, 2019).

Conclusions

While RWL through fluid restriction appears to decrease absolute sIgA levels it does not negatively impact secretion rate. The present study did not find incidence of URTI from this decrease in mucosal immunity, but this study did not examine post-competition illness so caution should be exercised as decreased immunity may increase risk of illness. Additionally, athletes who underwent RWL present to competition with significantly less compartmental water levels, they did increase some, but not all of these levels over the course of competition through *ad libitum* consumption. The stressor of RWL, combined with the physical and psychological stressors of competition may also make post-competition illness more likely and repeatedly utilizing unhealthy RWL may promote acute or long-term adverse health effects similar those seen in combat and other weight-controlled sports. Practitioners should be wary of inducing too great a body mass loss through fluid restriction for fear of exacerbating these negative health effects. Further research should be conducted to determine what effects there are on performance after undergoing RWL and if there are lasting effects to health or infection rates following these activities. While assaying sIgA is not a practical method of monitoring immunity, URTI surveys combined with %bm changes and USG may provide coaches cost-effective tools to educate athletes about weight loss practices and evaluate competition preparation.

Conflicts of interest - The authors have no conflicts of interest relevant to this article.

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