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# Changes of Hydration Measures in Elite National Collegiate Athletic Association Division I Wrestlers

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**Purpose:** To evaluate the changes in the state of hydration in elite National Collegiate Athletic Association (NCAA) Division I college wrestlers during and after a season. **Methods:** Ohio State University wrestling team members ( $N = 6$ ; mean [SD] age = 19.6 [1.1] y; height = 171.6 [2.9] cm; body mass = 69.5 [8.1] kg) gave informed consent to participate in the investigation with measurements (ie, body mass, urine-specific gravity [USG; 2 methods], Visual Analog Scale thirst scale, plasma osmolality) obtained during and after the season. **Results:** Measurements for USG, regardless of methods, were not significantly different between visits, but plasma osmolality was significantly ( $P = .001$ ) higher at the beginning of the season—295.5 (4.9)  $\text{mOsm}\cdot\text{kg}^{-1}$  compared with 279.6 (6.1)  $\text{mOsm}\cdot\text{kg}^{-1}$  after the season. No changes in thirst ratings were observed, and the 2 measures of USG were highly correlated ( $r > .9$ ,  $P = .000$ ) at each time point, but USG and plasma osmolality were not related. **Conclusions:** A paradox in the clinical interpretation of euhydration in the beginning of the season was observed with the USG, indicating that the wrestlers were properly hydrated, while the plasma osmolality showed they were not. Thus, the tracking of hydration status during the season is a concern when using only NCAA policies and procedures. The wrestlers did return to normal euhydration levels after the season on both biomarkers, which is remarkable, as previous studies have indicated that this may not happen because of the reregulation of the osmol-regulatory center in the brain.

**Keywords:** dehydration, thirst, urine-specific gravity, plasma osmolality, combative sports

For over 20 years, there have been concerns about the potential negative physiological effects of repeated body-mass losses over a wrestling season to “make weight” through a variety of methods including starvation, fluid restriction, and exercise.<sup>1-3</sup> In 1998, a study by Yankanich et al<sup>1</sup> was particularly frightening, as data in Penn State wrestlers demonstrated a reregulation of the osmol-regulatory center in the brain. Specifically, plasma osmolality did not differ whether the wrestler chose to lose 6% body mass in a gradual, moderate, or rapid manner. All plasma osmolality values were well above normal ranges suggesting that the volume of water in the body was reserved for this repeated process for “making weight” and, thus, a new threshold for normal plasma osmolality was created in wrestlers who typically lose this amount of body mass before a match.

The National Collegiate Athletic Association (NCAA) has initiated steps to mitigate these challenges by implementing a minimal weight program (ie, minimum weight loss for the season at 5% body fat)<sup>4</sup> with official day-of precompetition weigh-ins 11 to 2 hours in advance to help ensure the safe participation of the athletes. In addition, the NCAA has identified a urine-specific gravity (USG) value of less than or equal to 1.020  $\text{g}/\text{cm}^3$  as an indicator of proper hydration. Any value that is greater than 1.020  $\text{g}/\text{cm}^3$  is considered “failed,” and the wrestler must be retested no sooner than 24 hours after the initial assessment. USG has been used predominately in

large groups as a time efficient, safe, noninvasive, inexpensive, and perceived accurate indicator of hydration. The inherent challenge in utilizing USG for assessment lies in its capacity to shift after relatively modest consumption of fluids (591–1000 mL) and an overnight fast.<sup>3</sup> More recent studies have shown that the consumption of 1000 mL of water reduced USG to acceptable values (ie, from 1.026 to 1.013  $\text{g}/\text{cm}^3$ ), but whether this measure of dehydration is reflected in the plasma osmolality values has been questioned and is an important point requiring further study, especially in group of elite collegiate wrestlers making weight over an entire season.<sup>5,7</sup>

To gain an understanding of the differences of hydration in the collegiate sport of wrestling, comparisons of hydration status at the beginning of the season and after the season has ended are needed to help evaluate the different biomarkers of hydration status. Measurement of plasma osmolality is considered the “gold standard” test for hydration status, ranging from 280 to 285  $\text{mOsm}\cdot\text{kg}^{-1}$  for healthy individuals. For some individuals, wrestlers in particular, it has been observed that the plasma osmolality can reregulate this value to much higher than 285  $\text{mOsm}\cdot\text{kg}^{-1}$ . However, for wrestlers in particular, it has been shown that this can reregulate to higher values.<sup>1,7</sup>

Recent studies have called into question the equivalency of USG and plasma osmolality because their interpretation of hydration or the level of dehydration has varied in athletes. In addition, thirst may influence the subjective feelings of fatigue or loss of vigor, but attempts to measure somatosensory gating and performance are far from conclusive.<sup>8</sup> In a study by Oppliger et al,<sup>9</sup> it was observed that of the 27 subjects tested, 31.3% of the euhydrated subjects (true negative) were correctly classified for the 1.020 cutoff for USG, and 80.0% of the dehydrated (true positive) were correctly classified. This is the only study that shows a

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significant variation may exist in the relationship between USG and plasma osmolality. Thus, it might be hypothesized that the clinical interpretation of dehydration may not be equitable between the 2 different methods in elite collegiate wrestlers. This may be due to a new regulatory “normal” in their osmol-regulatory center in the brain. Concerns also exist if returning to normal values will occur after the season when the challenges of making weight are no longer imminent and when wrestlers feel free to eat and drink *ad libitum*.<sup>17</sup> Therefore, the primary purpose of this study was to examine the hydration state of a group of elite collegiate wrestlers at the beginning of their wrestling season and after the season using both USG and plasma osmolality to determine if hydration status using these biomarkers for hydration provide the same clinical interpretation. A secondary purpose was to compare 2 methods of measuring USG.

## Methods

### Design

In this study, a group of elite (Big Ten Championship-winning) wrestlers was tested at 2 interval time points. Thus, this was a rare opportunity to follow up on some questions and gain insight into the evaluation of hydration that has been a concern for us and the NCAA for several years. Testing was accomplished after the wrestlers began their season to allow for any typical physiological adjustments to the physical and weight loss demands of the new season to occur. Over the season, they wrestled, on average, 20 (3.5) matches and made weight for each of the matches. Specifically, we tested them on December 12, 2017, after they had completed 2 tournaments and 4 matches, and then tested them again on March 22, 2018, 5 days after the National Championships, to allow for physiological equilibration after the season to occur. This allowed us to view what might be termed a more “normative physiological status” for the wrestlers during training, competing, and making weight for competitions, and then compare it with their hypothesized baseline after the season.

### Subjects

Each subject was 18 years or older and signed an institutionally approved informed consent document to participate in the study after being informed of the risks and benefits of the investigation. The study was approved by The Ohio State University’s institutional review board for the use of human subjects in research. Participants ranged across the college weight classes with the exception of the heavyweight class. Subject characteristics were as follows:  $N = 6$ ; mean (SD): age 19.6 (1.1) y, height 171.6 (2.9) cm, body mass = 69.5 (8.1) kg. At the time of each testing session, none of the subjects were injured and all were fit for participation in the sport. Each had been involved in both wrestling and conditioning activities, and all had been competitive wrestlers from 12 to 14 years, competing at all levels.

### Experimental Procedures

Testing was done from 06:00 to 09:00 in the morning for each wrestler, with a similar time (within 1 h) for each athlete. Upon check-in, body mass and height were determined using a clinical scale/stadiometer (Seca 763 scale/stadiometer; Seca Corp, Chino, CA). Logs of body mass for the prior week and hydration (fluid intake) for fluid intake for the prior 24 hours before testing were collected. The wrestlers then provided a urine sample for

immediate analysis of USG using a handheld refractometer and a pen refractometer for cross-comparison of the same sample.

Following the urine sample, each wrestler completed the Visual Analog Scale (VAS) thirst scale and a categorical thirst scale associated with the VAS to measure their perceived level of thirst.<sup>10,11</sup> Then, subjects were seated comfortably while a trained phlebotomist obtained approximately 10 mL of blood from the antecubital vein via 23-gauge butterfly needle into a sodium heparin vacutainer. Blood was centrifuged using a Sorvall Legend XT centrifuge (Thermo Fisher Scientific Inc, Waltham, MA) at 2000 rpm for 10 minutes, and plasma was harvested and aliquoted into 1.5-mL osmometer-specific tubes.

A high-precision TS400 digital Clinical Refractometer (Reichert Inc, Buffalo, NY) was used for all experiments using a human USG scale. These measures, performed in duplicate, were used for hydration assessment compared with the plasma osmolality measures. We then had the opportunity to use a Atago Pen-Urine SG Refractometer (Atago U.S.A., Inc, Bellevue, WA) to compare the values with those from the standard manual Reichert refractometer to see if the values were similar for each instrument. All studies were conducted with the instrument and materials at ambient temperature to prevent any delays for specimen temperature equilibration. Samples were obtained and immediately tested within 1 hour of collection.

### Osmolality Assay Details

Plasma osmolality was then assayed using the Micro-Osmette Model 5004 Automatic Osmometer following the protocol recommendations from Precision Systems Inc (Natick, MA). Each sample was tested in triplicate and averaged to the final value, unless one value was an outlier with assay variances within 5%.

### Statistical Analyses

The data were presented as mean (SD). Assumptions for the statistical approach were examined before analyses and were met. Data were analyzed using a dependent *t* test to determine the differences between the 2 testing time points for the biomarkers. To view the relationship between selected variables, a simple correlation was run for selected variables using Pearson product-moment correlation coefficients. Test-retest reliability intraclass correlation coefficients for USG measures used in this study were  $R_s \geq .98$ . SPSS software (version 25; IBM Corp, Armonk, NY) was used for the analyses. Significance in this study was defined as  $P \leq .05$ .

## Results

The primary finding of this study was that there was a significant difference in the clinical interpretation of hydration level using the plasma osmolality and the USG measurements as had been recently warned for these 2 measures.<sup>5</sup>

One unique aspect of this study was that we also evaluated USG via both the manual and pen refractometers. The same sample was tested using both instruments. USG, tracked in a similar manner for each subject at both testing time points, showed a strong significant correlation between the 2 at both tests,  $r = .9$  ( $P = .000$ ) and  $.9$  ( $P = .000$ ), respectively. There were no significant differences between the 2 measurements regardless of the method used to determine USG (eg, mean [SD]; visit 1: manual method 1.023 [0.009] and pen method 1.018 [0.10]; visit 2: manual method 1.016 [0.010] and pen method 1.0178 [0.10]). However,

4 of the wrestlers demonstrated values greater than the 1.020 value set by the NCAA, as a cutoff for adequate USG in the beginning of the season, while only 2 of them after the season.

Interestingly, plasma osmolality was significantly ( $P = .001$ ) lower after the postseason visit when compared with the beginning of the season. The mean (SD) responses were 295.5 (4.9) and 279.6 (6.1)  $\text{mOsm}\cdot\text{kg}^{-1}$  for visit 1 and visit 2, respectively. All wrestlers were over the 285  $\text{mOsm}\cdot\text{kg}^{-1}$  threshold for hydration at the beginning of the season with 2 wrestlers over 300  $\text{mOsm}\cdot\text{kg}^{-1}$ . After the season, only one wrestler was just over the 285  $\text{mOsm}\cdot\text{kg}^{-1}$  value.

## Body Mass

Body mass was averaged for the week prior to testing to evaluate changes in body mass prior to competition. When compared with their competitive weight class, the wrestlers were challenged with an average of 4.5 (2.4) kg of body mass to lose in the beginning of the season to make weight. After the season, they had gained an average of 5.2 (2.3) kg above their competitive weight classes. There was no significant difference in body mass from the beginning of the season and the weight they needed to lose to “make weight” compared with the body mass gained back after the season ended.

## VAS Thirst Scale

The thirst scale was analyzed by measurements both categorically as well as on the VAS 100-mm scale. No significant differences were observed between the beginning of the season and after the season for either of the thirst scales. The numeric and categorical values demonstrated almost identical ratings ( $r = .9$ ,  $P = .001$ ). When analyzed categorically, the scale was broken down into 4 sections to determine the wrestlers’ perceived level of thirst at the time of each test. During the wrestling season, one wrestler complained of low thirst ( $\text{VAS} \leq 3$ ), 4 wrestlers complained of moderate thirst ( $\text{VAS} = 4-6$ ), and one wrestler complained of severe thirst ( $\text{VAS} \geq 7$ ). Interestingly, after the season, almost an identical profile was seen in the wrestlers’ thirst ratings, with one wrestler having low thirst ( $\text{VAS} \leq 3$ ) and the other 5 wrestlers still complaining of moderate thirst ( $\text{VAS} = 4-6$ ). The mean categorical thirst score at the beginning of the season was 5.26 (1.65; range: 3-7), which is considered in range for the moderate level of thirst distress. Following the season, thirst values were 4.34 (1.70; range: 3-6). Interestingly, most of the wrestlers struggled with thirst even after the season was over, which is a phenomenon that requires further elucidation. When evaluated further, it was discovered that the individuals who perceived themselves most thirsty were indeed the most dehydrated at each test visit.

## Discussion

The primary findings of this study were that the collegiate wrestlers in our sample were more dehydrated at the beginning of the season when compared with after the season. Furthermore, the magnitude of this dehydration was greater when viewed from the measurement of plasma osmolality than USG. Also, these 2 measurement techniques did not match each other in the clinical interpretation of hydration status, thus leading one to question if the sole use of USG for the assessment of hydration status is appropriate.<sup>5</sup>

The controversy of the measurement technique was recently brought to the forefront in a study by Sommerfield et al<sup>5</sup> who showed the lack of similarity between measures of USG and plasma osmolality. The reasons for this difference may be based

on the theory that wrestlers have created a new osmol-regulatory set point, which is not reflected in the USG measurements.<sup>1</sup> This could indicate that wrestlers have a larger reservoir or higher level of overall body water as a conduit to rapid weight loss. Changes in urinary output can be seen throughout the day. This was observed by Zambraski et al,<sup>2</sup> when wrestlers were tested at weigh-in, before the match, and postcompetition, revealing their ability to rehydrate post weigh-in before their match and go back into a dehydrated state postcompetition. Plasma osmolality does not tend to fluctuate as quickly, as observed by Kraemer et al,<sup>7</sup> when testing at rest across a tournament, but it has been observed at values reaching as high as 320  $\text{mOsm}\cdot\text{kg}^{-1}$  for some wrestlers postmatch.

The USG values showed minimal changes from the beginning of the season to postseason, 1.023 (0.009) to 1.016 (0.010), indicating only a minor change in the hydration status. Conversely, the plasma osmolality changed from 295.5 (4.9) to 279.6 (6.1)  $\text{mOsm}\cdot\text{kg}^{-1}$ . Therefore, is it possible that the mechanisms related to the osmol-regulation in the hypothalamus were compensating to preserve water while “making weight” giving the appearance of hydration, as noted in our previous research.<sup>1</sup> The USG and the plasma osmolality biomarkers were not tracking the same way and reflected a dramatic difference in the interpretation of the 2 biomarkers in elite wrestlers at the beginning of the season.

In a study by Ratamess et al,<sup>6</sup> their research team examined a season of changes in NCAA Division III wrestlers for USG. They demonstrated significant elevations only the day prior to a meet. Based on their data, it again brings into question whether USG can accurately reflect hydration status during a training week when plasma osmolality tends to trend higher and maintain its homeostasis at a higher level. It is known that dramatic body mass loss of 5% to 6% can result in performance deficits during a tournament format for both strength and power.<sup>7</sup> Interestingly, the 2 methods of measuring USG were highly correlated to each other, but both were not significantly related to plasma osmolality. This lends some validation to the pen method, but it still has the same problems as the other manual method by not accurately reflecting the gold standard of hydration, plasma osmolality.

Again, as noted in the study by Sommerfield et al,<sup>5</sup> different athletes, including wrestlers, can find similarity of the 2 measures, while many others do not. In other words, the matching of USG and plasma osmolality might reflect the same level of dehydration, while in others, or at other times, it may not. The disparity in this study was greater in the beginning of the season than it was after, when all but one of the wrestlers returned to normal ranges for both USG and plasma osmolality. The fact that plasma osmolality returned to normal values is noteworthy, as it indicates the concern for a permanent change in the hypothalamus osmol-regulatory center taking place with repeated weight loss events over a season. Obviously, this is a question that requires further study, as such a permanent change could produce negative health effects in the long term.<sup>1</sup>

Surprisingly, the wrestlers’ thirst ratings did not differ significantly between the 2 visits. As noted previously, this may be a concern that, after the season, thirst sensation did not reflect the euhydration indicated in the urine and plasma biomarkers. When evaluated further, it was discovered that the individuals who perceived themselves most thirsty were indeed the most dehydrated at each test visit. It is well known that “thirst” is a key factor in telling the body that it is hypohydrated, and it can persist into dehydrated conditions as well.<sup>12</sup> This is in response to arise in core body temperature, food intake (prandial), and signals from the

circadian clock. The perceived level of thirst, however, occurs in higher order centers in the brain, such as the anterior cingulate cortex and insular cortex, which receive information from midline thalamic relay nuclei.<sup>13</sup> In some cases, such as cycling, hypohydration impairs performance despite thirst not being reflective of the effects.<sup>14</sup> However, in wrestling opposed to other sports, reduction in water intake is the primary method of body-mass loss.<sup>15</sup> Thus, thirst may still be stimulated after the season due to the typical need for hydration throughout the season. Further work is needed on this phenomenon of the discord between thirst and euhydration.

## Practical Applications

From this study, it is apparent that care must be taken when working with wrestlers as to the assessment of hydration status. Unfortunately, USG may not yield the correct clinical interpretation for some wrestlers. Therefore, plasma osmolality should be checked at the beginning and throughout the season to see if their hydration status is truly in the normal ranges.

## Conclusions

In summary, this study showed a significant difference in plasma osmolality between test visits, but it failed to discover a significant difference in USG values. Thus, although USG values indicated that the wrestlers were euhydrated, the plasma osmolality indicated more severe hypohydration. We demonstrated a strong association between 2 types of USG methods (manual vs pen) at both testing time points. Finally, this is the first study to demonstrate, in a small group of highly elite wrestlers, that changes in the osmol-regulatory center in the hypothalamus may not be long term as almost all the wrestlers returned back to normal ranges after the season.

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