Validity Of Urine Specific Gravity When Compared With Plasma Osmolality As A Measure Of Hydration Status In Male And Female NCAA Collegiate Athletes

By: Lesley M. Sommerfield, **Steven R. McAnulty**, Jeffrey M. McBride, Jennifer J. Zwetsloot, Melanie D. Austin, Jonathan D. Mehlhorn, Mason C. Calhoun, Juliane O. Young, Traci L. Haines, & Alan C. Utter

Abstract

The purpose of this study was to evaluate the response of urine specific gravity (Usg) and urine osmolality (Uosm) when compared with plasma osmolality (Posm) from euhydration to 3% dehydration and then a 2-hour rehydration period in male and female collegiate athletes. Fifty-six National Collegiate Athletic Association (NCAA) wrestlers (mean ± SEM); height 1.75 ± 0.01 m, age 19.3 ± 0.2 years, and body mass (BM) 78.1 ± 1.8 kg and 26 NCAA women's soccer athletes; height 1.64 ± 0.01 m, age 19.8 ± 0.3 years, and BM 62.2 ± 1.2 kg were evaluated. Hydration status was obtained by measuring changes in Posm, Uosm, Usg, and BM. Male and female subjects dehydrated to achieve an average BM loss of 2.9 ± 0.09% and 1.9 ± 0.03%, respectively. Using the medical diagnostic decision model, the sensitivity of Usg was high in both the hydrated and dehydrated state for males (92%) and females (80%). However, the specificity of Usg was low in both the hydrated and dehydrated states for males (10 and 6%, respectively) and females (29 and 40%, respectively). No significant correlations were found between Usg and Posm during either the hydrated or dehydrated state for males or females. Based on these results, the use of Usg as a field measure of hydration status in male and female collegiate athletes should be used with caution. Considering that athletes deal with hydration status on a regular basis, the reported low specificity of Usg suggests that athletes could be incorrectly classified leading to the unnecessary loss of competition.

Sommerfield, Lesley M.; **McAnulty**, **Steven R.**; McBride, Jeffrey M.; Zwetsloot, Jennifer J.; Austin, Melanie D.; Mehlhorn, Jonathan D.; Calhoun, Mason C.; Young, Juliane O.; Haines, Traci L.; Utter, Alan C. (2016). Validity of Urine Specific Gravity When Compared With Plasma Osmolality as a Measure of Hydration Status in Male and Female NCAA Collegiate Athletes. *The Journal of Strength & Conditioning Research*, August 2016 - Vol. 30, Iss. 8, pages 2219-2225. doi: 10.1519/JSC.0000000000001313. Publisher version of record available at: https://journals.lww.com/nsca-jscr/Fulltext/2016/08000/Validity_of_Urine_Specific_Gravity_When_Compared.17.aspx

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Abstract

Sommerfield, LM, McAnulty, SR, McBride, JM, Zwetsloot, JJ, Austin, MD, Mehlhorn, JD, Calhoun, MC, Young, JO, Haines, TL, and Utter, AC. Validity of urine specific gravity when compared with plasma osmolality as a measure of hydration status in male and female NCAA collegiate athletes. *J Strength Cond Res* 30(8): 2219–2225, 2016–The purpose of this study was to evaluate the response of urine specific gravity (U_{sg}) and urine osmolality (U_{osm}) when compared with plasma osmolality (P_{osm}) from euhydration to 3% dehydration and then a 2-hour rehydration period in male and female collegiate athletes. Fifty-six National Collegiate Athletic Association (NCAA) wrestlers (mean ± *SEM*); height 1.75 ± 0.01 m, age 19.3 ± 0.2 years, and body mass (BM) 78.1 ± 1.8 kg and 26 NCAA women's soccer athletes; height 1.64 ± 0.01 m, age 19.8 ± 0.3 years, and BM 62.2 ± 1.2 kg were evaluated. Hydration status was obtained by measuring changes in P_{osm}, U_{osm}, U_{sg}, and BM. Male and female subjects dehydrated to achieve an average BM loss of 2.9 ± 0.09% and 1.9 ± 0.03%, respectively. Using the medical diagnostic decision model, the sensitivity of U_{sg} was high in both the hydrated and dehydrated state for males (92%) and females (80%). However, the specificity of U_{sg} was low in both the hydrated and dehydrated states for males (10 and 6%, respectively) and females (29 and 40%, respectively). No significant correlations were found between U_{sg} and P_{osm} during either the hydrated or dehydrated state for males or females. Based on these results, the use of U_{sg} as a field measure of hydration status in male and female collegiate athletes should be used with caution. Considering that athletes deal with hydration status on a regular basis, the reported low specificity of U_{sg} suggests that athletes could be incorrectly classified leading to the unnecessary loss of competition.

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Key Words dehydration, urine osmolality, division I athletes, euhydration

Introduction

Dehydration, a common occurrence among many athletic populations, can have detrimental performance effects on athletes if not properly monitored. In athletic populations, proper hydration and fluid replacement are essential to maintain performance levels, exercise sessions, and overall health (28). Hydration status is often overlooked as a necessary part of training and competition. Previous research has shown that as little as 2–3% body weight loss due to dehydration can compromise exercise performance, heat dissipation, and cardiovascular function (18).

Within these athletic populations, there are substantial differences in hydration status especially among males and females. Men typically have higher sweating rates than women primarily because men have larger body mass (BM) and higher metabolic rates when exercising (23). The main outcome of a recent study by Eijsvogels et al. (8) demonstrated that 98 subjects (21–82 years old, 56 men and 42 women) walked 30–50 km at a self-selected pace, found that men lost significantly more BM due to water loss as compared with women (−1.6 vs. −0.9%, respectively) and had a higher incidence of dehydration (34 vs. 12%, respectively). It was concluded in that study that men might be more susceptible to dehydration than women (8). Volpe et al. (28) compared the prepractice hydration status of National Collegiate Athletic Association (NCAA) Division I athletes and found that more men than women (47 vs. 28%, respectively) seem to be hypohydrated before practice. In that study, 263 subjects (138 men and 125 women, aged 18–23 years old) had a urine sample collected before practice for the assessment of U_{sg} and also completed a fluid intake questionnaire.

In previous investigations, several methods have been used to measure hydration status. P_{osm} is often considered the most valid technique for assessing hydration status because P_{osm} is tested in a laboratory under controlled conditions where body fluids are stable and equilibrated (3). However, in daily activities, body fluids are hardly ever stable so in some practical settings urinary measurements (i.e., U_{osm} and U_{sg}) can be accurate representations of hydration status. In addition, U_{osm} and U_{sg} are not as invasive as P_{osm} (26), and U_{sg} has been found to be an inexpensive, simple, fast, and accurate indicator of hydration status before exercise (2–4,16). A study by Armstrong et al. (5) employed 9 highly trained male cyclists, during a 42-hour period, dehydrated to a state of 3.7% of BM, cycle to exhaustion, and then orally rehydrated for 21 hours. Results of this study demonstrated that urinary measurements were valid and reliable indicators of hydration status and could be used in field settings, as U_{sg} and U_{osm} were significantly correlated ($r = 0.98$, $p < 0.001$). It has been shown that the loss of BM of 3–5% due to acute exercise causes the U_{osm} concentration to increase and the U_{sg} to be higher than normal (10,19).

In the position statement by the American College of Sports Medicine (ACSM), the biomarkers for hydration status cutoffs (which are used in this study) are $P_{osm} < 290$ m_{osm} (milliosmole)$\cdot kg^{-1}$, $U_{sg} < 1.020$, and $U_{osm} < 700$ $m_{osm} \cdot kg^{-1}$ (1). To date, there is conflicting evidence in the literature on U_{sg} and U_{osm} ability to detect hydration status, as compared with P_{osm} in both male and female athletes in a dehydrated state. A study conducted by Oppliger et al. (19) found that only 65% of the athletes (51 subjects total, 16 from a division I wrestling program, 31 from a division III wrestling program, and 4 physically active nonwrestlers) were correctly classified using U_{sg} and 63% using U_{osm} against the criterion measure of P_{osm}. Kovacs et al. (15) enrolled 8 well-trained male cyclists to bike until they reached a BM loss of 3% by dehydration and found that none of the urinary measurements had a strong correlation with postexercise hydration levels ($p > 0.05$). In contrast, Hamouti et al. (12) had 18 aerobically trained male athletes cycle to 1, 2, and 3% BM loss and found that U_{sg} was just as predictive as P_{osm} to detect low levels of exercise-induced dehydration ($p \leq 0.05$). To our knowledge, there have been no previous studies where U_{sg}, U_{osm}, and P_{osm} have been tested during acute dehydration in female athletes. Therefore, the purpose of this study was to first evaluate the response of U_{sg} and U_{osm} to a change in hydration status from euhydration to 3% dehydration and a 2-hour rehydration period, then assess the accuracy of U_{sg} and U_{osm} against a gold-standard measure, P_{osm}, in male and female collegiate athletes. We hypothesized that the response of U_{sg} and U_{osm} to a change in hydration status would be similar to the findings of Utter et al. (27) where both would significantly increase from predehydration to postdehydration and then return to baseline at the 2-hour rehydration period. We also hypothesized that U_{sg} and U_{osm} would be accurate indicators of hydration status when compared with P_{osm} in both male and female collegiate athletes.

Methods

Experimental Approach to the Problem

The specific aim of this study was to first evaluate the response of U_{sg} and U_{osm} to a change in hydration status from euhydration to 3% dehydration and a 2-hour rehydration period, then to assess the accuracy of U_{sg} and U_{osm} against the gold-standard measure, P_{osm}, in male and female collegiate athletes. Hydration status was calculated by measuring changes in P_{osm}, U_{sg}, U_{osm}, and BM all of which are considered standard laboratory indices (1). The research experiment followed a repeated measures design in which each subject served as their own control. Subjects reported to the Human Performance Laboratory once for orientation and later that same day for subsequent measurements of P_{osm}, U_{sg}, U_{osm}, and BM during the dehydration/rehydration trials.

Subjects

National Collegiate Athletic Association wrestlers from Appalachian State University (ASU) and Gardner Webb University ($n = 56$) and ASU women's soccer players ($n = 26$) who competed during the 2014–2015 season participated in this study. Subject characteristics for the males were as follows: (mean ± *SEM*); height 1.75 ± 0.01 m, age 19.3 ± 0.2 years, age range 18–22 years, average duration of wrestling experience 9.6 ± 0.5 years, weight 78.1 ± 1.8 kg, and perfect body fat (%BF) 13.9 ± 0.6%. Subject characteristics for the females were as follows: (mean ± *SEM*); height 1.64 ± 0.01 m, age 19.8 ± 0.3 years, average duration of soccer

Table 1. Subject characteristics.

	Males, $n = 56$	Females, $n = 26$
Height (m)	1.75 ± 0.01	1.64 ± 0.01*
Age (y)	19.3 ± 0.2	19.8 ± 0.3
Years of experience (y)	9.6 ± 0.5	15.1 ± 0.3*
Weight (kg)	78.1 ± 1.8	62.2 ± 1.2*
Percent fat (%)	13.9 ± 0.6	20.3 ± 0.7*
Urine specific gravity	1.027 ± 0.001	1.021 ± 0.001*
Urine osmolality ($m_{osm} \cdot kg^{-1}$)	966.8 ± 25.9	737.4 ± 50.5*
Plasma osmolality ($m_{osm} \cdot kg^{-1}$)	280.4 ± 2.2	281.2 ± 2.2

*Statistical significance at $p < 0.025$.

Male hydrated		Posm			Female hydrated		Posm		
		> 290 mosm/kg	≤ 290 mosm/kg	Total			> 290 mosm/kg	≤ 290 mosm/kg	Total
Usg	≥ 1.020	TP 22% (n = 12)	FP 69% (n = 38)	50	Usg	≥ 1.020	TP 15% (n = 4)	FP 58% (n = 15)	19
	< 1.020	FN 2% (n = 1)	TN 7% (n = 4)	5		< 1.020	FN 4% (n = 1)	TN 23% (n = 6)	7
	Total	13	42	Grand Total 55		Total	5	21	Grand Total 26
		Sensitivity 92%	Specificity 10%				Sensitivity 80%	Specificity 29%	

Figure 1. Medical diagnostic decision model for U_{sg} cutoff 1.020 in the hydrated state for males and females. True condition is represented by dehydration ($P_{osm} > 290\ m_{osm} \cdot kg^{-1}$) and a negative condition is represented by hydration ($P_{osm} \leq 290\ m_{osm} \cdot kg^{-1}$). A negative test is represented by $U_{sg} < 1.020$ and a positive test represented by $U_{sg} \geq 1.020$. Subjects correctly classified by the test are represented by TP and TN cells. TP, true positives; TN, true negatives; FP, false positives; FN, false negatives.

experience 15.1 ± 0.3 years, weight 62.2 ± 1.2 kg, and %BF 20.3 ± 0.7%. Significant differences were found between sex for the following variables: height (m), years of experience (years), weight (kg), percent fat (%), U_{sg}, and U_{osm} ($m_{osm} \cdot kg^{-1}$) (Table 1). All the subjects competed at the NCAA Division I level. Both wrestling teams were tested in the month of October (preseason) and the soccer team in the month of November (postseason). This study was approved by the Institutional Review Board for investigations involving human subjects at ASU. Subjects were informed of the risks and benefits of the investigation before signing an institutionally approved informed consent document to participate in the study.

Procedures

Subjects came to the ASU Human Performance Laboratory for orientation and the subsequent dehydration/rehydration trials. Subjects were instructed to report to the laboratory in a euhydrated state. Experimental sessions began at either 8:00 AM or 2:00 PM for all subjects. Subjects were screened for proper hydration status by obtaining a baseline urine specimen for measurement of U_{sg}. On arrival in the laboratory BM, height, body composition (skinfold thickness), U_{sg} (Atago optical refractometer), U_{osm}, and P_{osm} were obtained. P_{osm} and U_{osm} were determined via freezing point depression with an osmometer (Model 3250; Advanced Instruments, Inc., Norwood, MA, USA) calibrated to the manufacturer specification. Plasma and urine samples were taken at 4 time points throughout the study (predehydration, postdehydration, 1-hour rehydration, and 2-hour rehydration). All blood samples were collected by either registered nurses or phlebotomists. Immediately on acquisition, blood samples were centrifuged down, separating the plasma from the red blood cells. After aseptic technique, plasma was then

Male dehydrated		Posm			Female dehydrated		Posm		
		> 290 mosm/kg	≤ 290 mosm/kg	Total			> 290 mosm/kg	≤ 290 mosm/kg	Total
Usg	≥ 1.020	TP 65% (n = 35)	FP 28% (n = 15)	50	Usg	≥ 1.020	TP 16% (n = 4)	FP 48% (n = 12)	16
	< 1.020	FN 5% (n = 3)	TN 2% (n = 1)	4		< 1.020	FN 4% (n = 1)	TN 32% (n = 8)	9
	Total	38	16	Grand Total 54		Total	5	21	Grand Total 25
		Sensitivity 92%	Specificity 6%				Sensitivity 80%	Specificity 40%	

Figure 2. Medical diagnostic decision model for U_{sg} cutoff 1.020 in the dehydrated state for males and females. True condition is represented by dehydration ($P_{osm} > 290\ m_{osm} \cdot kg^{-1}$) and a negative condition is represented by hydration ($P_{osm} \leq 290\ m_{osm} \cdot kg^{-1}$). A negative test is represented by $U_{sg} < 1.020$ and a positive test represented by $U_{sg} \geq 1.020$. Subjects correctly classified by the test are represented by TP and TN cells. TP, true positives; TN, true negatives; FP, false positives; FN, false negatives.

aliquoted by 0.5 ml samples into labeled 1 ml sample tubes, and immediately frozen in liquid nitrogen. Urine samples were aliquoted in the same manner and immediately frozen in liquid nitrogen. Samples were stored at −80° C and later analyzed. For analysis, once samples were thawed, using aseptic technique, 0.25 ml of each sample was pipetted into a disposable 2-ml tube and placed in the osmometer for analysis in duplicate measures. Body composition was assessed from a 3-site skinfold (triceps, subscapular, and abdominal for males and triceps, suprailiac, and abdominal for females) test using a Lange caliper (Cambridge Scientific Industries, Inc., Cambridge, MD, USA). Body density (D_b) was determined from the 3 skinfold measures using the prediction equation by Lohman (17) for males and Jackson and Pollock (14) for females. Percent BF was determined from D_b using the Brozek equation (6) for males and (13) for females.

Subjects were instructed to decrease BM by 3% through controlled dehydration. Acute dehydration was induced by having the subjects participate in their standard exercise regime (2-hour practice session) under supervision of a certified coach. Subjects were asked to report back to the laboratory after they had attempted to reach their weight loss goal. On completion of dehydration, a second measure of body weight, U_{sg}, P_{osm}, U_{osm}, and BM were obtained. During the 2-hour rehydration period, subjects were instructed to consume a carbohydrate-electrolyte solution (6%, or 60 $g \cdot L^{-1}$) (Gatorade, Barrington, IL, USA). The carbohydrate-electrolyte beverage contained 20 $mmol \cdot L^{-1}$ of sodium and 3.2 $mmol \cdot L^{-1}$ of potassium. This solution was chosen because it has been seen to restore plasma osmolality at 120 minutes recovery after a 2–3% reduction in body weight (27). All beverages were provided to the subjects by research assistants during the trials. During the first 20 minutes of rehydration, subjects consumed beverage equal to one-half of their body weight loss. From 21 to 40 minutes of rehydration, subjects consumed a second volume of beverage to replace 100% of their body weight loss. Additional measures of body weight, U_{sg}, P_{osm}, and U_{osm} were obtained at 60 and 120 minutes.

Statistical Analyses

Values are expressed as mean ± *SEM*. Dependent variables were analyzed using a 1-way repeated-measures analysis of

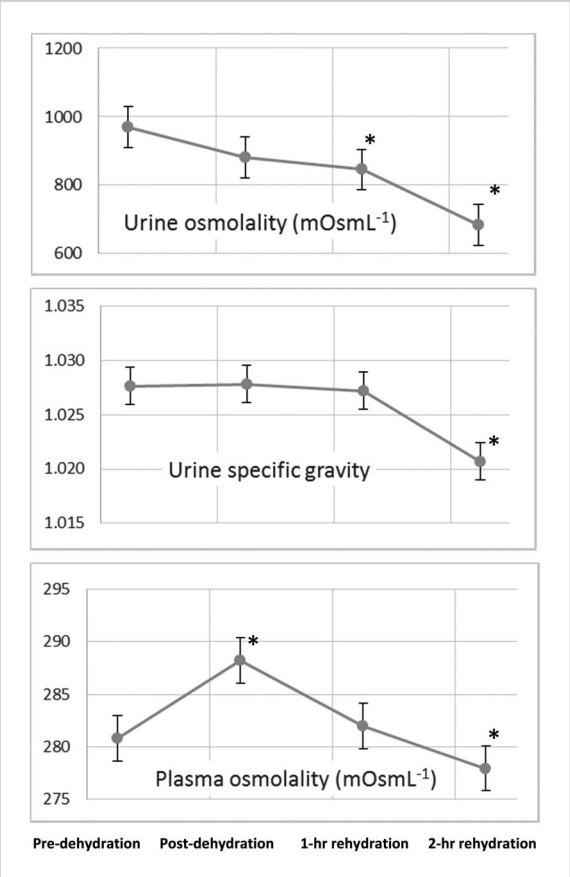

Figure 3. Urine osmolality, urine specific gravity, and plasma osmolality measurements at predehydration, postdehydration, and 1 and 2-hour rehydration in males. *Significantly different from baseline, $p < 0.016$.

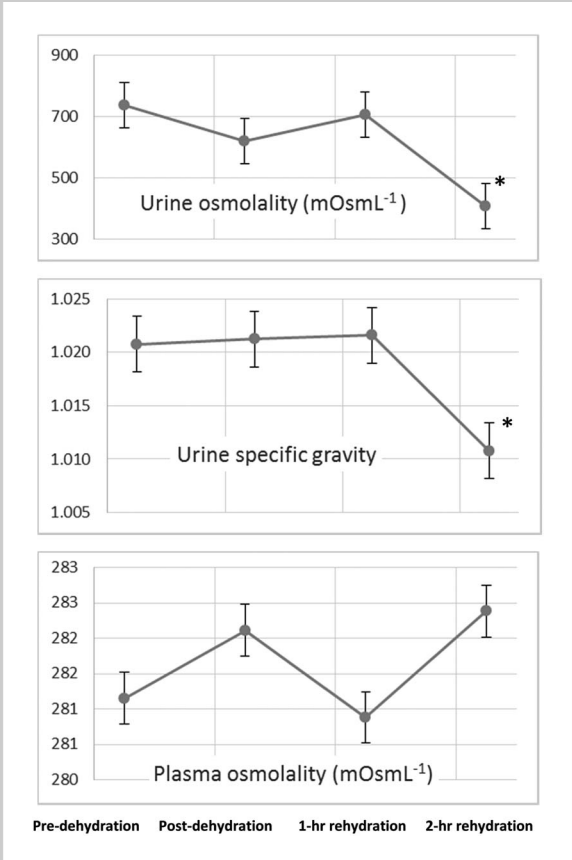

Figure 4. Urine osmolality, urine specific gravity, and plasma osmolality measurements at predehydration, postdehydration, and 1 and 2-hour rehydration in females. *Significantly different from baseline, $p < 0.016$.

Table 2. Male measures of hydration status throughout the trials.

Variable name	Prehydration	Postdehydration	1-h rehydration	2-h rehydration
Urine osmolality ($m_{osm} \cdot kg^{-1}$)	966.8 ± 25.9	882.3 ± 30.5	846.7 ± 26.8*	675.0 ± 48.1*
Urine specific gravity	1.027 ± 0.001	1.028 ± 0.001	1.027 ± 0.001	1.021 ± 0.001*
Plasma osmolality ($m_{osm} \cdot kg^{-1}$)	280.4 ± 2.2	288.1 ± 2.4*	282.0 ± 2.3	278.0 ± 2.4*

*Significantly different from baseline, $p < 0.016$.

variance. Significant main effects were evaluated with paired *t*-tests using a Bonferroni adjustment, with statistical significance set at $p < 0.025$. Independent *t*-tests were used to examine differences between sex for baseline subject characteristics.

The quantitative assessment using the medical decision model calculates 2 values, sensitivity and specificity. Sensitivity is the ability of a test to classify correctly all screened individuals who actually have the condition. Sensitivity is defined as the number of true positives (TP) divided by the sum of TP and false negatives (FN). Specificity is the ability of the test to identify only nonconditioned individuals who actually do not have the condition. It is defined as the number of true negatives (TN) divided by the sum of false positives (FP) and TN.

For this study, the "condition" is hydration status and presence of the condition would be dehydration represented by $P_{osm} > 290\ m_{osm} \cdot kg^{-1}$ and absence of the condition would be hydration represented by $P_{osm} \leq 290\ m_{osm} \cdot kg^{-1}$. The "diagnostic test" being evaluated in this study is U_{sg}. A U_{sg} value <1.020 represents a negative test, whereas a value ≥ 1.020 represents a positive test.

Figure 1 (hydrated state) and Figure 2 (dehydrated state) represent a contingence table created to compute sensitivity and specificity for the diagnostic test U_{sg} with a cutoff for dehydration at ≥ 1.020 for the male and female subjects in the study. True positives ($U_{sg} \geq 1.020$ and $P_{osm} > 290\ m_{osm} \cdot kg^{-1}$) are shown in the upper left box, TN ($U_{sg} < 1.020$ and $P_{osm} \leq 290\ m_{osm} \cdot kg^{-1}$) in the lower right box, FP ($U_{sg} \geq 1.020$ and $P_{osm} \leq 290\ m_{osm} \cdot kg^{-1}$) in the upper right box, and FN ($U_{sg} < 1.020$ and $P_{osm} > 290\ m_{osm} \cdot kg^{-1}$) in the lower left box. Sensitivity (bottom left box) and specificity (bottom right box) have been calculated according to their definitions.

Results

Male subjects dehydrated to achieve an average BM loss of 2.9 ± 0.09%. Body mass changes (kg) throughout the study for males were as follows: predehydration (baseline) = 78.1 ± 1.8, postdehydration = 75.8 ± 1.8, and 2-hour rehydration = 77.8 ± 1.8. Female subjects dehydrated to achieve an average BM loss of 1.9 ± 0.03%. Body mass changes (kg) throughout the study for females were as follows: predehydration (baseline) = 62.2 ± 1.2, postdehydration = 61.0 ± 1.2, and 2-hour rehydration = 62.0 ± 1.3. For rehydration, subjects were provided with beverage amounts equal to 100% of their BM loss. Male subjects were able to regain 2.6 ± 0.09% of the BM loss, whereas females were able to regain 1.6 ± 0.06% of the BM loss during the 2-hour rehydration period.

Significant main effects ($p < 0.025$) were found for P_{osm}, U_{osm}, and U_{sg} for males (Figure 3) and U_{osm} and U_{sg} for females (Figure 4). P_{osm} for the males significantly increased from baseline to postdehydration (280.4 ± 2.2 to 288.1 ± 2.4 $m_{osm} \cdot kg^{-1}$), decreased at the 1-hour rehydration period (282.0 ± 2.3 $m_{osm} \cdot kg^{-1}$) and returned to below baseline at the 2-hour rehydration period (278.0 ± 2.1 $m_{osm} \cdot kg^{-1}$) (Table 2, Figure 3). A nonsignificant change was found for P_{osm} in females from baseline to postdehydration (281.2 ± 2.2–282.1 ± 2.4 $m_{osm} \cdot kg^{-1}$) and a decrease at the 1-hour

Table 3. Female measures of hydration status throughout the trials.

Variable name	Prehydration	Postdehydration	1-h rehydration	2-h rehydration
Urine osmolality ($m_{osm} \cdot kg^{-1}$)	737.4 ± 50.5	617.6 ± 60.1	700.0 ± 52.3	407.2 ± 67.3*
Urine specific gravity	1.021 ± 0.001	1.021 ± 0.002	1.022 ± 0.002	1.011 ± 0.001*
Plasma osmolality ($m_{osm} \cdot kg^{-1}$)	281.2 ± 2.2	282.1 ± 2.4	280.9 ± 2.5	282.4 ± 2.9

*Significantly different from baseline, $p < 0.016$.

rehydration period (280.9 ± 2.5 $m_{osm} \cdot kg^{-1}$) (Table 3, Figure 4). For males, U_{osm} significantly decreased from baseline (966.8 ± 25.95 $m_{osm} \cdot kg^{-1}$) and at all 3 time points thereafter (882.3 ± 30.5 to 846.7 ± 26.8 to 675.0 ± 48.15 $m_{osm} \cdot kg^{-1}$). There was a significant decrease in U_{osm} from baseline to the 2-hour rehydration period (407.2 ± 67.35 $m_{osm} \cdot kg^{-1}$) for females. The U_{sg} for the males slightly increased from baseline to postdehydration (1.027 ± 0.001 to 1.028 ± 0.001), and significantly decreased below baseline at the 2-hour rehydration period (1.021 ± 0.001). For females, U_{sg} remained constant from baseline to postdehydration (1.021 ± 0.001 to 1.021 ± 0.002), and significantly decreased below baseline at the 2-hour rehydration period (1.011 ± 0.002). No significant correlations were found between U_{sg} and P_{osm} during either the hydrated or dehydrated state for males or females.

Discussion

This study evaluated U_{sg} and U_{osm} as markers of hydration status against P_{osm}. To our knowledge, this study is the first investigation to use the medical diagnostic decision model to evaluate dehydration when using U_{sg} in both male and female athletes during hydrated and dehydrated conditions. Opplinger et al. (19) has previously reported a high sensitivity and low specificity for U_{sg} when compared with P_{osm}. Results of this study found a high prevalence (58–69%) of FP in both the hydrated and dehydrated conditions for males and females. Opplinger et al. (19) reported that 68.8% of subjects tested were found to be FP, whereas similarly in this study, 69% of males and 58% of females indicated FP when tested in a hydrated state. The results of this study demonstrated that the percentage of FP did decrease in the dehydrated condition for both males and females (28 and 48%, respectively) but are still considered high especially in the female population. A study by Popowski et al. (22) also compared P_{osm} with U_{sg} in which 12 male subjects dehydrated to 1, 3, and 5% BM loss and found that FP occurred with a probability of 33 (baseline), 100, 58, and 33%, respectively. Although the study by Popowski (22) had a relatively small sample size, our results are consistent with their findings in that with progressive dehydration the percentage of FP decreases when assessed by U_{sg}.

Previous investigations have demonstrated a poor association between P_{osm} and urinary measures of hydration status. Armstrong et al. (4) measured subjects in a variety of conditions, including before and after rest in an air-conditioned room, exercise in a heated environment, and after an outdoor tennis match, and found that no urinary measures significantly correlated with P_{osm} in any of the conditions evaluated. Similarly, Singh and Peters (25) had male and female amateur runners complete a 3-day trail run, subjects were examined before and after run each day, and they reported that urinary measures also did not significantly correlate with P_{osm}. Singh and Peters (25) suggested that the reason for the nonsignificant correlations between P_{osm} and urinary markers was the result of a delayed response between acute changes in hydration status as measured in both the blood and urine. The lack of significant changes in P_{osm} for females in this study may be a result of only a 1.9% decrease in BW when compared with a 2.9% reduction for males. This also suggests that an acute BW reduction secondary to dehydration of 1.9% in females was not detectable by changes in P_{osm}.

Our results demonstrated high values of U_{sg} at baseline in the male athletes (1.027 ± 0.001). Similarly, a study by Pettersson and Berg (20) that measured U_{sg} the morning of competition in 63 (20 females and 43 males) elite wrestlers, judokas, boxers, and taekwondo athletes and found that mean U_{sg} was 1.029 ± 0.006 and that 47.6% of the athletes were hypohydrated (>1.030). In that study none of the participating athletes were found to be well hydrated and only 7 of 63 (11%) of the athletes had U_{sg} values <1.020. Another study by Phillips et al. (21) measured U_{sg} in the first urine void (baseline), before, and after training of 14 junior male elite soccer players and found that 77% of the subjects were hypohydrated at baseline on days 1 and 3 and 62% on day 2. They also reported no significant differences found in U_{sg} between baseline and before or after training. Gibson et al. (9) tested hydration status of 34 junior female elite soccer players during two 90-minute training sessions and found that the baseline mean U_{sg} was 1.018 ± 0.009 of which is consistent with results of this study. In this study and previous investigations mentioned a U_{sg} threshold of >1.020 have been used as the dehydration cutoff point. Although this cutoff value has been supported by the ACSM, it has been suggested that the U_{sg} threshold to detect dehydration should be raised to >1.025 in athletes with relative high muscle mass (7,11). Results of this study demonstrate that 69% of males and 58% of females had $P_{osm} < 290$ although their U_{sg} was >1.020. The reason for the high prevalence of FP in this study is unclear. U_{sg} is influenced by the amount of solutes, such as glucose and protein (24) found in the urine, therefore it is possible that supplement use could increase U_{sg}. Supplement use was not evaluated or quantified in this investigation.

In addition to U_{sg}, this study evaluated P_{osm} at baseline and found that both the male and female athletes were considered hydrated (280.8 ± 2.1 and 281.2 ± 2.2, respectively). Contrary Yankanich et al. (29) examined the hydration status through P_{osm} of 12 NCAA Division I wrestlers by having them lose 6% BW in varying rates (gradual, moderate, or rapid weight loss) throughout 6 days. Results of that study demonstrated that P_{osm} was elevated when subjects were in the euhydrated state (>300 $m_{osm} \cdot kg^{-1}$). The authors concluded that wrestlers regulate P_{osm} at a higher level than the general population because they consistently lose weight by heat and exercise-induced dehydration. The Yankanich et al. study used 12 subjects, whereas this study used 56 males and 26 females, which could account for the difference in the P_{osm} values at baseline between the 2 investigations.

Practical Applications

As stated in the ACSM position statement, there are many physiological and health reasons for screening, detecting,

and minimizing dehydration in athletic populations. This is the case for athletes who deliberately or involuntarily experience dehydration, such as the subjects of this study (wrestlers and female soccer players). Dehydration to even 2–3% of BM can have considerable effects on an athlete's performance and overall well-being, so the use of field tests to monitor hydration status becomes warranted. The reported low specificity of U_{sg} for this study and others suggests that athletes could be incorrectly classified as dehydrated leading to the unnecessary removal from competition. Coaches and athletic trainers must continue to educate their athletes on safe weight loss methods in weight-classified sports and consider alternative measures to assess hydration to be used in conjunction with U_{sg}. Future research using U_{sg} as a measure of hydration status should be evaluated with P_{osm} in both male and female athletes to see if the results are conclusive with this study. In addition, additional research using all biomarkers of hydration status with female populations is warranted.

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