

Assessment of Hydration Status at a Single Time Point in Athletes

Konrad Witek^{1*}, Agata Gontarek², Dariusz Turowski¹, Sylwia Lewandowska-Pachecka³ and Benedykt H Opaszowski¹



¹Biochemistry Department, Institute of Sport–National Research Institute, Poland

²Endocrinology Department, Institute of Sport–National Research Institute, Poland

³Faculty of Pharmacy with the Laboratory Medicine Division, Medical University of Warsaw, Poland

*Corresponding author: Konrad Witek, Biochemistry Department, Institute of Sport–National Research Institute, Poland

ARTICLE INFO

Received: 📅 October 20, 2020

Published: 📅 November 03, 2020

Citation: Konrad W, Agata G, Dariusz T, S Lewandowska-Pachecka, Benedykt HO. Assessment of Hydration Status at a Single Time Point in Athletes. Biomed J Sci & Tech Res 31(4)-2020. BJSTR. MS.ID.005126.

Keywords: Hydration Status; Osmolality; Specific Gravity; Athletes

ABSTRACT

Proper hydration status is important for athletes, because of its significant influence on physical fitness and mental perception during exercise. Assessment of hydration status is conducted mainly using urinary and plasma indices, which are not always useful at a single time measurements. The study aim was to compare different markers of hydration status in athletes, measured at a single time point. Eighty-nine volleyball players (37 women, 52 men, mean age 16.9y) were recruited. Serum and urine samples were analysed for specific gravity, osmolality, urine and serum osmolality ratio and water deficit. We found a strong correlation between urine specific gravity and osmolality, and only weak correlations with serum osmolality. Urine indices identified 61.8 to 70.8% cases of dehydration, while serum osmolality only 32.6%. Water-deficit was calculated using two different equations which gave contrary results ($1.38 \pm 0.74\%$ vs $-0.33 \pm 0.88\%$). In conclusion, the urinary and plasma indices identified a high occurrence rate of dehydration in athletes, but results derived from different parameters were contradictory. The $U_{osm}:Posm$ ratio seems to be a useful indicator of dehydration, but should be specified with a reference range or cut-off value.

Introduction

Maintaining the correct water balance is one of the most dynamic and important process in human body [1]. This is especially important for athletes, because dehydration can have a negative influence on physical and cognitive performance [2,3]. As such, monitoring athlete hydration status is crucial for optimising performance during training sessions and competitions. The assessment of hydration is mainly based on urine and blood indices, with no consensus regarding the “gold standard” in dehydration markers [2]. One of the most popular markers is plasma osmolality, which reflects intracellular dehydration [3]. Other common indices are urine osmolality and urine specific gravity. Shirreffs [4] concluded that urinary markers are more sensitive indicators of dehydration, but they may have a delay in the reaction. Urine measurements seems to be secondary to plasma osmolality changes [5]. Searching for better indicators of dehydration, researchers

have tested composite measures calculated on the basis of blood or urine tests. For example, Cheuvront et al. [6] tested a series of water-deficit equations, and they found significant improvements after replacement in the equation of sodium to plasma osmolality. Likewise, Armstrong et al. [7] suggested that urine:plasma osmolality ratio could be good indicator of hydration status, measured at a single time point.

Parallel to the search of reliable dehydration markers, studies have investigated the utility of identifying cut-off values. The physiological regulation of plasma osmolality makes that normal values vary about 1-2% from value of 287mOsm/kg in well-hydrated individuals [8]. Based on the small deviation, a cut-off of 290mOsm/kg would seem suitable for classifying subjects as being either euhydrated or dehydrated [9]. Manz and Wentz [7] suggested cut-off value for urinary osmolality of 830mOsm/kg. Baron et al. [8]

suggest that osmolality over 800mOsm/kg is a more appropriate threshold for differentiation between euhydrated and slightly dehydrated status. In the case of urine specific gravity, a number of studies indicate cut-off values of 1.020-1.025 for the upper range of euhydrated state [10-12]. Given the discrepancies, the aim of this study was to compare different markers of hydration status in athletes, measured at a single time point.

Materials and Methods

Eighty-nine volleyball players (37 women and 52 men, anthropometric data in Table 1) participated in this study. Testing was conducted in a laboratory at the Department of Biochemistry, Institute of Sport-National Research Institute in Warsaw, Poland. This study was approved by the Ethical Research Committee at the Institute of Sport-NRI in Warsaw. Participants were arrived at laboratory between 7:00 and 9:00am. The players were at the beginning of the league season and had two training sessions daily. Venous blood and urea samples were collected after arrival on an empty stomach and transferred to the laboratory within 1 hour of collection.

Table 1: Anthropometric characteristic of the study group (mean±SD).

Sex	n	Age	Body mass	Body height	BMI
		[years]	[kg]	[m]	
Female	37	16.4±1.4	67.7±7.6	182.5±6.7	20.3±2.2
Male	52	17.4±0.9	83.9±8.0	195.5±6.4	22.0±1.9
All	89	16.9±1.2	77.2±11.2	190.1±9.1	21.3±2.2

Whole blood was collected into different tubes (Vacuette vacuum system tubes, Greiner bio-One, Kremsmünster, Austria): for glucose measurement containing sodium fluoride, for sodium measurement containing lithium heparin, for measurements in serum containing coagulation accelerator (and left to clot for 30 minutes and centrifuged at 2000g for 10 minutes). Urine was collected in a sterile urine beaker. Serum (S_{osm}) and urine (U_{osm}) osmolality was measured by freezing point depression method (OS3000 osmometer, Marcel, Zielonka, Poland), Urine Specific Gravity (USG) using a handheld refractometer (Atago PAL-10s, Tokyo, Japan). For further calculations, sodium concentration (Na^+) was measured in whole blood using ion analyser (pHOx plus M, Nova Biomedical, Waltham, MA, USA), plasma glucose and serum urea concentrations were measured using colorimetric methods with Cobas Integra400 biochemical analyser (Roche Diagnostic, Basel, Switzerland) with original manufacturer reagent kits. Water deficit was calculated by equations [6]:

$$WD_1 = 0.6 \times \text{body mass} \times [1 - (140 \div Na^+)], \text{ and}$$

$$WD_2 = 0.6 \times \text{body mass} \times [1 - (290 \div S_{osm})]$$

Additional osmolality variable was computed by the formula:

$$OSM_{cal} = 2 \times [Na^+] + [glucose] + [urea]$$

All assays were completed on the same day. Testing was conducted in a laboratory certified from the Polish Centre for Accreditation (no. AB 946).

Statistical Analyses

All data are presented as mean±SD. The Shapiro-Wilk test was employed to determinate data normality. Because most of the data did not follow a normal distribution, Wilcoxon signed-rank tests was used for a comparison of mean differences. Relationships between variables were also determined using Pearson's correlation coefficient. The level of $p \leq 0.05$ was considered significant. Variables were analysed with Statistica 13 software (TIBCO Software INC., Palo Alto, CA, USA).

Results

Table 2 shows the measured parameters, and Table 3 shows correlation between them. Significant but weak correlations were observed between U_{SG} and S_{osm} or WD_2 . Interestingly, S_{osm} strongly correlated with WD_2 but there were only weak correlation with $U_{osm} : S_{osm}$ ratio. Calculated osmolality was significantly higher than measured one, and correlation between them was statistically important but rather weak. We observed statistically significant differences between water deficit equations WD_1 and WD_2 but with opposite mean values and weak correlation between them. In approximately half of the athletes (49.3%) WD_1 results were above 2%, what can be considered as important dehydration, while by WD_2 only 1.1% reached this threshold.

Table 2: Values of measured and calculated parameters (mean±SD).

	Female	Male	All
USG	1.023±0.006	1.024±0.005	1.023±0.005
U_{osm} [mOsm/kg]	835.5±204.8	835.6±199.9	835.5±200.8
S_{osm} [mOsm/kg]	286.4±6.8	289.1±4.6	287.9±5.7#
OSM_{cal} [mOsm/kg]	297.6±5.4	299.6±4.2	298.8±4.8#
$U_{osm} : S_{osm}$ ratio	2.91±0.70	2.89±0.68	2.90±0.69
WD_1 [L]	1.12±0.72	1.56±0.70	1.38±0.74*
WD_2 [L]	-0.54±0.98	-0.18±0.78	-0.33±0.88*

Note: Statistically significant relationships between: # S_{osm} and OSM_{cal} , * WD_1 and WD_2 ($p < 0.05$, Wilcoxon signed-rank test).

There were large discrepancies between numbers of results beyond the adopted cut-off values (Table 4). The highest percentage of athletes with dehydration shows OSM_{cal} and the lowest S_{osm} . There were no significant correlation between measured or calculated parameters and the age of the athletes.

Table 3: Values of measured and calculated parameters (mean±SD).

	U_{SG}	U_{osm}	S_{osm}	OSM_{cal}	$U_{osm}:S_{osm}$ ratio	WD_1	WD_2
U_{SG}							
U_{osm}	0.971*						
S_{osm}	0.293*	0.304*					
OSM_{cal}	0.16	0.191	0.235*				
$U_{osm}:S_{osm}$ ratio	0.969*	0.997*	0.230*	0.171			
WD_1	0.156	0.175	0.228*	0.945*	0.156		
WD_2	0.293*	0.307*	0.991*	0.247*	0.233*	0.234*	

Note: *Statistically significant correlation ($p < 0.05$).

Table 4: Percentage of results above adopted cut-off values.

Parameter	U_{SG}	U_{osm}	S_{osm}	OSM_{cal}
		[mOsm/kg]	[mOsm/kg]	[mOsm/kg]
Cut-off value	1.020 ^a	800 ^b	290 ^c	290 ^c
All group [%]	70.8	61.8	32.6	94.4

Note: Cut-off values adopted from: ^aSawka et al [14], ^bManz and Wentz [9], ^cKenefick et al [8].

Discussion

Maintaining proper hydration status is important for athletes, because its impact on physical fitness and mental perception [13]. A common practice in sport is the monitoring of hydration using different biomarkers [14]. Problem of maintaining appropriate hydration status is often studied in disciplines with weight categories, e.g. combat sports [15]. In our study, more than 60% athletes had results of urine indices above cut-off values, shows dehydration status. Considering serum osmolality, only about one-third of the athletes tested were classified as dehydrated. It is noteworthy that the urine indices identified a similar percentage of euhydrated subjects. The greatest percentage of above cut-off values was observed in OSM_{cal} . It is interesting, because only in 33.7% of cases $[Na^+]$ concentration were above 145mmol/L, what indicates hypertonicity [10]. The results show that the problem of dehydration applies even in those sports that seem less exposed to the occurrence of this phenomenon. One of the most accepted indicators of hydration is plasma osmolality [11]. However, Hamouti et al. [12] suggested that P_{osm} is less sensitive after an overnight recovery, and urine specific gravity and osmolality are better under these circumstances. In turn, Chevront and Kenefick [16] concluded that urine-based measurements are secondary to changes in P_{osm} for detecting dehydration. Shirreffs [4] stated that urinary measures could have a time lag over the short term.

In the current study, we found significant correlations between the urinary indices and S_{osm} . The percentage of urine results above the adopted cut-off values shows more dehydration cases when compared with data for S_{osm} . This finding partly confirms the assertion that plasma osmolality could better describe acute changes of hydration status. Although, we measured serum not

plasma osmolality, the results are interchangeable [10]. For an accurate assessment of hydration status in sport, it is important to determine appropriate cut-off values for different hydration biomarkers. Unfortunately, wide discrepancies exist in the proposed values for urine osmolality, ranging from 700mOsm/kg [17] to above 1000mOsm/kg [18]. We adopted a value of 800mOsm/kg as a meaningful threshold for differentiation between euhydrated and dehydrated status [7]. In reference to urine specific gravity, most authors apply 1.020 as a cut-off value [11]. Similarly, in case of plasma osmolality, a threshold value of 290mOsm/kg is widely accepted.

A lack of consensus around what constitutes the "gold standard" index for assessing hydration status has promoted studies in this area. Armstrong et al. [19] proposed the $U_{osm}:P_{osm}$ ratio as a potential hydration biomarker, which can be measured at a single time point. Results obtained in our study are similar to Armstrong's data on a low-volume drinkers group. To our knowledge, there are no specific reference range for this ratio, with values < 1.0 only indicating the existence of relative water excess. Our data highlight the need to determine reference range or cut-off value for this parameter. Two water-deficit equations were replicated in this work; the most common (WD_1) and the best according to the authors (WD_2). We found significant differences and in relation to other obtained results, the WD_1 equation seems to be more relevant. The percentage of results above 2% of water deficit, that is considered as significant for performance [20], were 49.4% for WD_1 and 1.1% for WD_2 . Thus, the WD_1 results are more convergent with other measures taken in this study. In conclusion, the occurrence frequency of dehydration in the athletes confirms the need for determination of reliable markers of hydration status in different sports disciplines. Urine is a more accessible material for research, but seems to be less effective

with only single measurements obtained. The $U_{osm}:P_{osm}$ ratio seems to be a useful indicator of dehydration status, but should be applied with a specified reference range or cut-off value. In future study should be investigated the need of determining the specific cut-off values for different sports disciplines.

Acknowledgment

The study was financially supported by Institute of Sport-National Research Institute, grant number: 103.04.

References

1. Jequier E, Constant F (2010) Water as an essential nutrient: the physiological basis of hydration. *Eur J Clin Nutr* 64(2): 115-123.
2. Armstrong LE (2007) Assessing hydration status: the elusive gold standard. *J Am Coll Nutr* 26: 575S-584S.
3. Cheuvront SN, Kenefick RW, Charkoudian N, Sawka MN (2013) Physiologic basis for understanding quantitative dehydration assessment. *Am J Clin Nutr* 97(3): 455-462.
4. Shirreffs SM (2003) Markers of hydration status. *Eur J Clin Nutr* 57: S6-S9.
5. Shoker AS (1994) Application of the clearance concept to hyponatremic and hypernatremic disorders: a phenomenological analysis. *Clin Chem* 40(7): 1220-1227.
6. Cheuvront SN, Kenefick RW, Sollanek KJ, Ely BR, Sawka MN (2013) Water-deficit equation: Systematic analysis and improvement. *Am J Clin Nutr* 97(1): 79-85.
7. Manz F, Wentz A (2003) 24-h hydration status: parameters, epidemiology and recommendations. *Eur J Clin Nutr* 57 Suppl 2: S10-S18.
8. Baron S, Courbebaisse M, Lepicard EM, Friedlander G (2015) Assessment of hydration status in a large population. *Br J Nutr* 113(1): 147-158.
9. Kenefick RW, Ely BR, Cheuvront SN, Palombo LJ, Goodman DA, et al. (2009) Prior heat stress: effect on subsequent 15-min time trial performance in the heat. *Med Sci Sports Exerc* 41(6): 1311-1316.
10. Hew-Butler TD, Eskin C, Bickham J, Rusnak M, Vander Meulen M (2018) Dehydration is how you define it: comparison of 318 blood and urine athlete spot checks. *BMJ Open Sport Exerc Med* 4(1): e000297.
11. Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, et al. (2007) American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc* 39(2): 377-390.
12. Hamouti N, Del Coso J, Mora-Rodriguez R (2013) Comparison between blood and urinary fluid balance indices during dehydrating exercise and the subsequent hypohydration when fluid is not restored. *Eur J Appl Physiol* 113(3): 611-620.
13. Maughan RJ, Shirreffs SM (2010) Dehydration and rehydration in competitive sport. *Scand J Med Sci Sports* 20: 40-47.
14. Lee EC, Fragala MS, Kavouras SA, Queen RM, Pryor JL, et al. (2017) Biomarkers in sports and exercise: tracking health, performance, and recovery in athletes. *J Strength Cond Res* 31(10): 2930-2937.
15. Zubac D, Marusic U, Karninčič H (2016) Hydration Status Assessment Techniques and Their Applicability Among Olympic Combat Sports Athletes. *Strength Cond J* 38(4): 80-89.
16. Cheuvront SN, Kenefick RW (2013) Comparison between blood and urinary indices for dehydration: A different interpretation. *Eur J Appl Physiol* 113(8): 2167-2168.
17. Cleary MA, Hetzler RK, Wasson D, Wages JJ, Stickley C, et al. (2012) Hydration behaviors before and after an educational and prescribed hydration intervention in adolescent athletes. *J Athl Train* 47(3): 273-281.
18. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, et al. (1994) Urinary indices of hydration status. *Int J Sport Nutr* 4(3): 265-279.
19. Armstrong LE, Johnson EC, Munoz CX, Le Bellego L, Klein A, et al. (2013) Evaluation of Uosm: Posm ratio as a hydration biomarker in free-living, healthy young women. *Eur J Clin Nutr* 67(9): 934-938.
20. Adan A (2012) Cognitive performance and dehydration. *J Am Coll Nutr* 31(2): 71-78.

ISSN: 2574-1241

DOI: 10.26717/BJSTR.2020.31.005126

Konrad Witek. Biomed J Sci & Tech Res



This work is licensed under Creative Commons Attribution 4.0 License

Submission Link: <https://biomedres.us/submit-manuscript.php>



Assets of Publishing with us

- Global archiving of articles
- Immediate, unrestricted online access
- Rigorous Peer Review Process
- Authors Retain Copyrights
- Unique DOI for all articles

<https://biomedres.us/>