



## LJMU Research Online

**Armstrong, LE, Kavouras, SA, Walsh, NP and Roberts, WO**

**Diagnosing dehydration? Blend evidence with clinical observations**

<http://researchonline.ljmu.ac.uk/id/eprint/25261/>

### Article

**Citation** (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

**Armstrong, LE, Kavouras, SA, Walsh, NP and Roberts, WO (2016)**  
**Diagnosing dehydration? Blend evidence with clinical observations.**  
**Current Opinion in Clinical Nutrition and Metabolic Care, 19 (6). pp. 434-438.**  
**ISSN 1363-1950**

LJMU has developed **LJMU Research Online** for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact [researchonline@ljmu.ac.uk](mailto:researchonline@ljmu.ac.uk)

<http://researchonline.ljmu.ac.uk/>

## 1 **Diagnosing dehydration? Blend evidence with clinical observations**

2

3 Lawrence E. Armstrong, Ph.D., FACSM<sup>1</sup>, Stavros A. Kavouras, Ph.D., FACSM<sup>2\*</sup>, Neil P. Walsh,  
4 Ph.D., FACSM<sup>3</sup>, and William O. Roberts, M.D., FACSM<sup>4</sup>

5

6 <sup>1</sup> University of Connecticut, Human Performance Laboratory, Storrs CT 06269-1110, USA; Tel:  
7 860.486.1120; e-mail: Lawrence.armstrong@uconn.edu

8 <sup>2</sup> University of Arkansas, Hydration Science Lab, Fayetteville AR 72701, USA; Tel: 479.575.5309; e-mail:  
9 kavouras@uark.edu

10 <sup>3</sup> Bangor University, Extremes Research Group, George Building, Bangor, Gwynedd, Wales, LL57 2PZ,  
11 United Kingdom; Tel: 44 (0) 1248 382756, ext 3480; e-mail: n.walsh@bangor.ac.uk

12 <sup>4</sup> University of Minnesota, Department of Family Medicine and Community Health, St Paul, MN 55106,  
13 USA; Tel: 651.772-3461; e-mail: rober037@umn.edu

14

### 15 **\*Corresponding Author**

16 Stavros A. Kavouras, Ph.D., FACSM

17 University of Arkansas

18 Hydration Science Lab

19 Fayetteville, AR 72701

20 USA

21 Office telephone: +1 (479) 445-7308

22 e-mail: kavouras@uark.edu

23

### 24 **Running Head**

25 Diagnostic Considerations for Dehydration

26

27 **ABSTRACT**

28 **Purpose of Review**

29 The purpose of the review is to provide recommendations to improve clinical decision making  
30 based on the strengths and weaknesses of commonly-used hydration biomarkers and clinical  
31 assessment methods.

32 **Recent findings**

33 There is widespread consensus regarding treatment, but not the diagnosis of dehydration. Even  
34 though it is generally accepted that a proper clinical diagnosis of dehydration can only be made  
35 biochemically rather than relying upon clinical signs and symptoms, no gold standard  
36 biochemical hydration index exists. Other than clinical biomarkers in blood (i.e. osmolality,  
37 BUN/creatinine) and in urine (i.e. osmolality, specific gravity), blood pressure assessment and  
38 clinical symptoms in the eye (i.e. tear production, palpitating pressure) and the mouth (i.e. thirst,  
39 mucous wetness) can provide important information for diagnosing dehydration.

40 **Summary**

41 It is recommended that clinical observations based on a combination of history, physical  
42 examination, laboratory values, and clinician experience remain the best approach to the  
43 diagnosis of dehydration.

44

45 **Keywords**

46 hydration assessment, hypovolemia, fluid balance, body water, hydration status

## 47 INTRODUCTION

48 Adults and children continuously lose and replace body water, and often develop mild, but not  
49 clinically significant dehydration several times each week. Although very mild dehydration of 1.5  
50 – 2 % body mass loss alters mood and results in reduced cognitive (1, 2) and physical (3)  
51 performance, it is easily corrected. When left chronically untreated, moderate-to-severe  
52 dehydration increases the risk of urinary tract infection, chronic kidney disease (4-6), and also  
53 increases medical costs, morbidity, and mortality (7). Unfortunately, despite numerous  
54 investigations (8), the methods of dehydration assessment have not been refined to the point  
55 that a single reference standard has been identified for clinical decision making (9); this  
56 magnifies the difficulty of diagnosing dehydration in clinical practice (9-12). This article provides  
57 recommendations to improve clinical decision making based on the strengths and weaknesses  
58 of commonly-used hydration biomarkers and clinical assessment methods.

59

### 60 **Scientific evidence that informs clinical observations**

61 We approached this problem from three perspectives: (a) rating the scientific and clinical value  
62 of hydration assessment techniques; (b) rating the time, monetary cost, and technical expertise  
63 required; and (c) incorporating the conclusions of previously published review papers. Table 1  
64 provides a synthesis of the findings of previous publications (9, 13-16) and consensus of the  
65 present authors.

66

[ Table 1 ]

67 There is widespread consensus regarding treatment, but not the diagnosis of dehydration.  
68 Although it is generally accepted that a proper clinical diagnosis of dehydration can only be  
69 made biochemically (e.g. using clinical laboratory tests), rather than relying upon clinical signs  
70 and symptoms (Table 1) (16), no gold standard biochemical hydration index exists (13, 16).  
71 The techniques presented in Table 1 include signs and symptoms that are frequently used in

72 clinical practice for screening purposes because of their relative simplicity, speed of  
73 measurement and low cost. Unfortunately, the teaching and choice of signs and symptoms are  
74 largely based on clinical experience and medical tradition (11, 16); very often, the underpinning  
75 scientific evidence supporting their use is weak (e.g., lack of comparison to a recognized  
76 criterion or reference standard). The holy grail of identifying a single gold standard hydration  
77 index is unrealistic given that the clinician evaluates different types of dehydration (e.g.  
78 hypertonic and isotonic), different severities of dehydration, and often observes a patient only  
79 once (i.e., static assessment in an emergency department), as opposed to monitoring hydration  
80 relative to a euhydrated baseline (i.e., dynamic assessment in a nursing facility). Further, the  
81 clinician accounts for the potentially confounding effects of illness and medications, and  
82 considers the desired precision, accuracy, cost, analytical time and expertise required to  
83 perform the measurement (Table 1).

84

85 Blood osmolality has been proposed as a suitable index of dehydration (typically defined as >  
86  $300 \text{ mOsm} \cdot \text{kg}^{-1}$ ) (9, 12); however, this is not universally accepted (13, 17). Evidence supporting  
87 blood osmolality as a hydration index typically comes from studies that incorporate a sweat-loss  
88 model of hypertonic hypovolemia in young, fit, and healthy individuals. As such, blood osmolality  
89 is unsuitable to detect isotonic hypovolemia that often results from illness and medications (e.g.,  
90 diuretics) in a clinical setting. This situation is compounded by a lack of standardization in blood  
91 osmolality measurements (calculated values versus direct measurements via osmometer, Table  
92 1) and other clinical laboratory indices of hydration.

93

94 Guidelines for the treatment of dehydration are widely accepted, as published by the U.S.  
95 Centers for Disease Control and Prevention, the World Health Organization, the American

96 Academy of Pediatrics, and the National Institute for Health and Clinical Excellence of the  
97 United Kingdom. Guidelines for the diagnosis of dehydration are not universally accepted.

98

### 99 **The decision algorithm**

100 From the clinical perspective, volume depletion (loss of sodium from the extracellular space)  
101 and dehydration (loss of water from the intracellular space) must be distinguished because this  
102 influences the type and rate of fluid and electrolyte replacement. At this time, the evaluation for  
103 both remains largely a clinically based process incorporating the patient history, physical  
104 examination, and available laboratory values. The history and presenting circumstances often  
105 drive the decision algorithm. Confounding factors influence the decision to treat for dehydration,  
106 including intravascular volume depletion in the face of obvious total body water increase with  
107 peripheral edema on physical exam.

108

[ Figure 1 ]

109 Clinical observations such as skin turgor, mucous membrane moisture, sunken eyes, and tear  
110 production can be helpful in children when multiple findings are present, but are not as reliable  
111 in the elderly (16). Physical examination measurements such as orthostatic blood pressure and  
112 heart rate responses support the clinical observation of dehydration. However, orthostatic  
113 changes can be difficult to obtain in a compromised patient and may reflect dilated lower  
114 extremity vasculature in an athlete post competition. Body weight can vary from day to day and  
115 is useful in the acute clinical setting when there is a reasonable baseline weight to compare to  
116 the current weight; however, variations in scales make this assessment less reliable. The  
117 admission body weight measurement provides a useful baseline to assess body fluid changes,  
118 especially when measured within a 24-h period on the same scale.

119

120 Clinical laboratory values are helpful in the context of the history and physical exam.  
121 BUN/creatinine ratio, hematocrit/hemoglobin ratio, serum sodium concentration, serum  
122 osmolality, and urine specific gravity are commonly measured in clinics, emergency  
123 departments and on the wards, but have not been validated as a reference standard. In  
124 particular, urine specific gravity reportedly is unreliable in diagnosing dehydration in children  
125 with gastroenteritis (18). Medications, especially from the diuretic classes, can confuse the  
126 biochemical picture by varying the renal clearance of water and electrolytes. Invasive  
127 procedures with central intravascular lines help establish the volume status and fluid balance of  
128 critically ill patients, but are not used in non-critical dehydration patients. Chronic kidney  
129 disease, heart failure, and other maladies that affect renal blood flow also confound the clinical  
130 picture and complicate diagnostic efforts. Recent evidence further complicates the assessment  
131 of hydration status, in that different hydration indices may validly identify dehydration in one  
132 circumstance but not another (19).

133

#### 134 **CONCLUSION**

135 Clearly, a pressing need exists for well-controlled studies of clinically relevant dehydration  
136 models (i.e., both hypertonic and isotonic hypovolemia) in appropriate patient populations (i.e.,  
137 other than athletes and military personnel) that identify hydration indices with scientific and  
138 clinical validity and precision. Only then can normal and clinically significant population ranges  
139 be determined. At present, clinical observations based on a combination of history, physical  
140 examination, laboratory values, and clinician experience remain the best approach to the  
141 diagnosis of dehydration. Figure 1 and Table 1 provide guidance to that end.

142

143 **KEY POINTS**

- 144       • Clinical observations based on a combination of history, physical examination, laboratory  
145       values, and clinician experience is the best approach to the diagnosis of dehydration.
- 146       • There is widespread consensus regarding treatment, but not the diagnosis of  
147       dehydration.
- 148       • There is a pressing need for well-controlled studies of clinically relevant dehydration  
149       models in appropriate patient populations (i.e., other than athletes and soldiers) that  
150       identify hydration indices with scientific and clinical validity and precision.
- 151



152 **Acknowledgements**

153 None

154 **Financial support and sponsorship**

155 None

156 **Conflicts of interest**

157 **LEA** is currently a consultant for Drinking Water Research Foundation, Alexandria VA and  
158 Danone Research, France; has received grants from Danone Research, France; is on the  
159 speaker's bureau for Drinking Water Research Foundation, Alexandria VA and Danone  
160 Research, France. **SAK** is currently a consultant for Quest Diagnostics, Secaucus, NJ and  
161 Danone Research, France; has active grants with Danone Research, France; is on the  
162 speaker's bureau for Danone Research, France. **NPW** has received a grant with HydraDX.

163 **WOR** None.

164

165 **REFERENCES AND RECOMMENDED READING**

166 Papers of particular interest, published within the annual period of review, have been highlighted  
167 as:

168 \* of special interest

169 \*\* of outstanding interest

170

171 1. Armstrong LE, Ganio MS, Casa DJ, Lee EC, McDermott BP, Klau JF, et al. Mild dehydration affects  
172 mood in healthy young women. *Journal of Nutrition*. 2012;142(2):382-8.

173 2. Watson P, Whale A, Mears SA, Reyner LA, Maughan RJ. Mild hypohydration increases the  
174 frequency of driver errors during a prolonged, monotonous driving task. *Physiol Behav*. 2015;147:313-8.

175 \*\*The results of the present study indicated that mild hypohydration increased minor driving errors  
176 compared to euhydration. The degree of the errors were comparable to the effects observed  
177 following ingestion of an alcoholic beverage.

178 3. Bardis CN, Kavouras SA, Kosti L, Markousi M, Sidossis LS. Mild hypohydration decreases cycling  
179 performance in the heat. 2013;45(9):1782-9.

180 4. Armstrong LE. Challenges of linking chronic dehydration and fluid consumption to health  
181 outcomes. *Nutr Rev*. 2012;70 Suppl 2:S121-7.

182 5. Clark WF, Sontrop JM, Huang S-H, Moist L, Bouby N, Bankir L. Hydration and Chronic Kidney  
183 Disease Progression: A Critical Review of the Evidence. *Am J Nephrol*. 2016;43(4):281-92.

184 \* This is a review on the effect of hydration in kidney health. The paper indicates that increase in water  
185 intake has beneficial effects on chronic kidney disease by suppressing vasopressin.

186 6. Sontrop JM, Dixon SN, Garg AX, Buendia-Jimenez I, Dohein O, Huang S-HS, et al. Association  
187 between water intake, chronic kidney disease, and cardiovascular disease: a cross-sectional analysis of  
188 NHANES data. *Am J Nephrol*. 2013;37(5):434-42.

- 189 7. Cowen LE, Hodak SP, Verbalis JG. Age-associated abnormalities of water homeostasis.  
190 *Endocrinol Metab Clin North Am.* 2013;42(2):349-70.
- 191 8. Cheuvront SN, Kenefick RW. Am I Drinking Enough? Yes, No, and Maybe. *J Am Coll Nutr.*  
192 2016;35(2):185-92.
- 193 \*\* This review discusses the adequacy of total water intake by two different angles: avoiding  
194 dehydration and balancing renal solute load.
- 195 9. Cheuvront SN, Kenefick RW, Charkoudian N, Sawka MN. Physiologic basis for understanding  
196 quantitative dehydration assessment. *American Journal of Clinical Nutrition.* 2013;97(3):455-62.
- 197 10. Hayajneh WA, Jdaitawi H, Al Shurman A, Hayajneh YA. Comparison of clinical associations and  
198 laboratory abnormalities in children with moderate and severe dehydration. *J Pediatr Gastroenterol*  
199 *Nutr.* 2010;50(3):290-4.
- 200 11. Roland D, Clarke C, Borland ML, Pascoe EM. Does a standardised scoring system of clinical signs  
201 reduce variability between doctors' assessments of the potentially dehydrated child? *J Paediatr Child*  
202 *Health.* 2010;46(3):103-7.
- 203 12. Sollanek KJ, Kenefick RW, Walsh NP, Fortes MB, Esmaeelpour M, Cheuvront SN. Assessment of  
204 thermal dehydration using the human eye What is the potential? *Journal of Thermal Biology.* 2012:1-7.
- 205 13. Armstrong LE. Assessing hydration status: the elusive gold standard. *J Am Coll Nutr.* 2007;26(5  
206 Suppl):575S-84S.
- 207 14. Kavouras SA, Johnson EC, Bougatsas D, Arnaoutis G, Panagiotakos DB, Perrier E, et al. Validation  
208 of a urine color scale for assessment of urine osmolality in healthy children. *Eur J Nutr.* 2016;55(3):907-  
209 15.
- 210 \* This study suggested that urine color is a valid marker to assess elevated urine osmolality in young  
211 healthy children.

212 15. McKenzie AL, Munoz CX, Ellis LA, Perrier ET, Guelinckx I, Klein A, et al. Urine color as an indicator  
213 of urine concentration in pregnant and lactating women. *Eur J Nutr*. 2015.

214 \* This study concluded that urine color is a valid marker of urine concentration for pregnant and  
215 lactating women.

216 16. Sinert R, Spektor M. Evidence-based emergency medicine/rational clinical examination abstract.  
217 Clinical assessment of hypovolemia. *Ann Emerg Med*. 2005;45(3):327-9.

218 17. Fortes MB, Owen JA, Raymond-Barker P, Bishop C, Elghenzai S, Oliver SJ, et al. Is this elderly  
219 patient dehydrated? Diagnostic accuracy of hydration assessment using physical signs, urine, and saliva  
220 markers. *Journal of the American Medical Directors Association*. 2015;16(3):221-8.

221 \* This study assessed the diagnostic ability of physical, urine and saliva hydration markers in older  
222 adults. An interesting finding was that saliva osmolality had superior diagnostic utility than plasma  
223 osmolality.

224 18. Steiner MJ, Nager AL, Wang VJ. Urine specific gravity and other urinary indices: inaccurate tests  
225 for dehydration. *Pediatr Emerg Care*. 2007;23(5):298-303.

226 19. Munoz CX, Johnson EC, DeMartini JK, Huggins RA, McKenzie AL, Casa DJ, et al. Assessment of  
227 hydration biomarkers including salivary osmolality during passive and active dehydration. *Eur J Clin Nutr*.  
228 2013.

229

230 **Figure 1 Legend**

231 Physical examination and laboratory measurements aid diagnosis when multiple findings exist

232

233 **Table 1 Title**

234 Comparison of research and clinical techniques to diagnose dehydration during a single

235 examination.

236

237

**Table 1.** Comparison of Research and Clinical Techniques to Diagnose Dehydration, Using a Single Measurement.

<b>Hydration Assessment Techniques</b>	<b>Patient Self-Evaluation</b>	<b>Cost Efficiency</b>	<b>Time Efficiency</b>	<b>Simplicity of Test</b>	<b>Scientific Value<sup>c</sup></b>
<b>Signs &amp; Symptoms</b>					
Dry mucous membrane		●●●●●	●●●●●	●●●○○	●○○○○
Skin turgor		●●●●●	●●●●●	●●○○○	●○○○○
Nail bed refill time (sec)		●●●●●	●●●●●	●●●○○	●○○○○
Thirst sensation (thirst scale rating)	✓	●●●●●	●●●●●	●●●●●	●●●○○
Respiratory pattern		●●●●●	●●●●●	●●●○○	●○○○○
Dry axilla		●●●●●	●●●●●	●●●●●	●○○○○
Seated systolic blood pressure (mmHg)		●●●●●	●●●○○	●●●○○	●●●●○
Blood pressure change supine/upright <sup>a</sup> (mmHg)	✓	●●●●●	●●●○○	●●●○○	●●●●○
Heart rate change supine/upright (beats·min <sup>-1</sup> )	✓	●●●●●	●●●●●	●●●●●	●●○○○
Absence of tears		●●●●●	●●●●●	●●●●●	●○○○○
Sunken eyes		●●●●●	●●●●●	●●●●●	●○○○○
Palpated intraocular pressure		●●●●●	●●●●●	●●●●●	●○○○○
Dark urine color (color chart rating)	✓	●●●●●	●●●●●	●●●●●	●●●○○
Body mass (kg)	✓	●●●●●	●●●●●	●●●●●	●○○○○
<b>Clinical Diagnostic Laboratory Tests</b>					
BUN/creatinine ratio		●●●○○	●●●○○	●●●○○	●●●●○
Serum sodium concentration (mEq·L <sup>-1</sup> or mmol·L <sup>-1</sup> )		●●●○○	●●●○○	●●○○○	●●●○○
Blood osmolality, calculated (mOsm·kg <sup>-1</sup> or mmol·kg <sup>-1</sup> )		●●●○○	●●●○○	●●○○○	●●●●○
Hematocrit/hemoglobin ratio		●●●○○	●●●○○	●●●○○	●●●○○
Mean corpuscular volume (fL)		●●●○○	●●●○○	●●●○○	●●●○○
Urine specific gravity		●●●●●	●●●○○	●●●○○	●●●●○
<b>Research Measurements</b>					
Isotope dilution, total body water (L)		●○○○○	●○○○○	●○○○○	●●●○○
Neutron activation analysis, fluid volumes and ionic content		●○○○○	●○○○○	●○○○○	●●●○○
Bioelectrical impedance analysis, total body water (L)		●●●○○	●●●○○	●●●○○	●●●○○
Body mass (kg)	✓	●●●●●	●●●●●	●●●●●	●○○○○
Blood osmolality, measured <sup>b</sup> (mOsm·kg <sup>-1</sup> or mmol·kg <sup>-1</sup> )		●●●○○	●●●○○	●●●○○	●●●●○
Urine osmolality (mOsm·kg <sup>-1</sup> or mmol·kg <sup>-1</sup> )		●●●○○	●●●○○	●●●○○	●●●●○
Salivary osmolality (mOsm·kg <sup>-1</sup> or mmol·kg <sup>-1</sup> )		●●●○○	●●●○○	●●●○○	●●●●○
Tear osmolality (mOsm·L <sup>-1</sup> or mmol·L <sup>-1</sup> )		●●●○○	●●●○○	●●●○○	●●●○○
Intraocular pressure (mmHg)		●●●○○	●●●○○	●●●○○	●●○○○

<sup>a</sup> lying to sitting, sitting to standing, lying to standing<sup>b</sup> measured via freezing point depression osmometry<sup>c</sup> considering measurement resolution, reliability and accuracy

●●●●● = high, ●●●○○ = medium &amp; ●○○○○ = low

240 Figure 1

