JAMDA xxx (2014) 1–8

JAMDA

journal homepage: www.jamda.com

Original Study

# Is This Elderly Patient Dehydrated? Diagnostic Accuracy of Hydration Assessment Using Physical Signs, Urine, and Saliva Markers

Matthew B. Fortes PhD [a,*], Julian A. Owen MSc [a], Philippa Raymond-Barker MSc [a], Claire Bishop MD [b], Salah Elghenzai MD [b], Samuel J. Oliver PhD [a], Neil P. Walsh PhD [a,*]

[a] School of Sport, Health and Exercise Sciences, College of Health and Behavioural Sciences, Bangor University, Bangor, United Kingdom
[b] Department of Geriatric Medicine, Gwynedd Hospital, Betsi Cadwaladr University Health Board, Bangor, United Kingdom

*Keywords:*
Dehydration
diagnosis
older
hypovolemia
osmolality
clinical

A B S T R A C T

*Objectives:* Dehydration in older adults contributes to increased morbidity and mortality during hospitalization. As such, early diagnosis of dehydration may improve patient outcome and reduce the burden on healthcare. This prospective study investigated the diagnostic accuracy of routinely used physical signs, and noninvasive markers of hydration in urine and saliva.
*Design:* Prospective diagnostic accuracy study.
*Setting:* Hospital acute medical care unit and emergency department.
*Participants:* One hundred thirty older adults [59 males, 71 females, mean (standard deviation) age = 78 (9) years].
*Measurements:* Participants with any primary diagnosis underwent a hydration assessment within 30 minutes of admittance to hospital. Hydration assessment comprised 7 physical signs of dehydration [tachycardia (>100 bpm), low systolic blood pressure (<100 mm Hg), dry mucous membrane, dry axilla, poor skin turgor, sunken eyes, and long capillary refill time (>2 seconds)], urine color, urine specific gravity, saliva flow rate, and saliva osmolality. Plasma osmolality and the blood urea nitrogen to creatinine ratio were assessed as reference standards of hydration with 21% of participants classified with water-loss dehydration (plasma osmolality >295 mOsm/kg), 19% classified with water-and-solute-loss dehydration (blood urea nitrogen to creatinine ratio >20), and 60% classified as euhydrated.
*Results:* All physical signs showed poor sensitivity (0%–44%) for detecting either form of dehydration, with only low systolic blood pressure demonstrating potential utility for aiding the diagnosis of water-and-solute-loss dehydration [diagnostic odds ratio (OR) = 14.7]. Neither urine color, urine specific gravity, nor saliva flow rate could discriminate hydration status (area under the receiver operating characteristic curve = 0.49–0.57, $P > .05$). In contrast, saliva osmolality demonstrated moderate diagnostic accuracy (area under the receiver operating characteristic curve = 0.76, $P < .001$) to distinguish both dehydration types (70% sensitivity, 68% specificity, OR = 5.0 (95% confidence interval 1.7–15.1) for water-loss dehydration, and 78% sensitivity, 72% specificity, OR = 8.9 (95% confidence interval 2.5–30.7) for water-and-solute-loss dehydration).
*Conclusions:* With the exception of low systolic blood pressure, which could aid in the specific diagnosis of water-and-solute-loss dehydration, physical signs and urine markers show little utility to determine if an elderly patient is dehydrated. Saliva osmolality demonstrated superior diagnostic accuracy compared with physical signs and urine markers, and may have utility for the assessment of both water-loss and water-and-solute-loss dehydration in older individuals. It is particularly noteworthy that saliva osmolality was able to detect water-and-solute-loss dehydration, for which a measurement of plasma osmolality would have no diagnostic utility.



The study was funded by HydraDx Inc. The company was interested in identifying if saliva indices other than those presented herein had utility for hydration assessment. MBF and PRB were employed as research assistants by HydraDx on this study.

* Address correspondence to Neil P. Walsh, PhD or Matthew B. Fortes, College of Health and Behavioural Sciences, Bangor University, Bangor LL57 2PZ, UK.
*E-mail addresses:* n.walsh@bangor.ac.uk (N.P. Walsh), m.fortes@bangor.ac.uk (M.B. Fortes).

http://dx.doi.org/10.1016/j.jamda.2014.09.012
1525-8610/

Dehydration in older adults is a significant clinical problem. A diagnosis of dehydration is associated with the presence of co-morbidities, longer hospital stay, additional future hospitalization, and higher mortality rates. [1–5] The point-prevalence of dehydration in community-dwelling older adults in the USA was reported as 17%–28%.[6,7] In many cases, simple and inexpensive oral rehydration is sufficient to treat dehydration and halt the progress of more serious fluid-deficit related illnesses such as acute kidney injury. However, upon hospitalization, many patients may be denied the correct course of treatment because of physician misdiagnosis of dehydration.[7] Therefore, accurate and early identification of dehydration in older adults admitted to hospital is vital to alleviate ill health and the significant economic burden of treating dehydration on healthcare.[1,2]

No single 'gold-standard' marker of hydration status exists,[8] although blood biochemistry including plasma osmolality, electrolytes, and blood urea nitrogen to creatinine ratio (BUN:Cr) represent criterion methods of identifying dehydration in a clinical setting.[9–12] However, blood sample collection is invasive and laboratory analysis is time-consuming, often delaying the course of treatment by hours. To aid an initial diagnosis of dehydration before requesting blood biochemistry confirmation, clinicians may use a variety of simple screening measures, albeit in a nonsystematic way, that may include presenting signs and symptoms of dehydration,[11,13,14] patient history,[13] orthostatic blood pressure change,[15] and/or urinary parameters.[16] Nevertheless, these screening methods are often characterized by poor diagnostic performance.[11,17–21] To confound hydration assessment further, the term 'dehydration' is poorly defined and is used to characterize many water and solute deficits relating to whole body fluid deficits.[7] In order to simplify clinical practice researchers have suggested the classification of clinical dehydration into 2 distinct types. First, water-loss dehydration (also termed hypertonic hypovolemia or intracellular dehydration) is hypertonic in nature and occurs when water loss proportionally exceeds solute loss. Water loss dehydration is typically defined as a plasma osmolality $\geq$295 mOsm/kg.[12,22] Second, water-and-solute-loss dehydration (also termed intravascular volume depletion or extracellular dehydration), which may be isotonic or hypotonic because of equal, or greater proportional loss of solutes than water,[10,12,23] and typically defined as a BUN:Cr $\geq$20 in the absence of hypertonicity.[22] To the best of our knowledge, there are few[18,19] rigorous studies that have investigated the diagnostic accuracy of clinical physical signs and/or urine indices to detect dehydration in hospitalized older adults using a criterion reference method, and none which have simultaneously assessed the utility of any hydration marker to assess both types of dehydration.

In a series of studies (in young healthy adults), we have shown that rapid measurements made from noninvasive collection of saliva fluid can be used to identify water-loss dehydration.[24–26] For example, decreases in whole saliva flow rate (SFR) and increases in whole saliva osmolality were shown to track progressive modest dehydration (equivalent to 1%–3% body mass loss). The utility of these novel saliva markers of dehydration has not yet been examined in a clinical, older adult population, although encouragingly, the presence of a dry tongue was identified as the clinical sign most strongly associated with dehydration in an elderly cohort.[14] To this end, the purpose of this prospective study was to determine, and compare, the diagnostic accuracy of clinical physical signs routinely used in hospital settings,[11,13,14] along with saliva (flow rate and osmolality) and urine indices (color and specific gravity),[27] to detect static (one-point in time) water-loss, and water-and-solute-loss dehydration in a hospitalized, older adult cohort using primary reference standards; plasma osmolality and BUN:Cr.[10,12,22,28]

## Methods

### *Experimental Design and Procedures*

The study was conducted as a prospective, hospital-based cross-sectional study. All measures of hydration status were performed within 30 minutes of admission, with no disruption to routine care in the following order; examination of physical signs of dehydration, collection of saliva, blood, and urine. For the reference standards of whole body hydration assessment, a blood sample was collected by the clinical research fellow or a specialist phlebotomist and analyzed for plasma osmolality (within 15 minutes) and BUN:Cr (within 2 hours). For consistency, all physical examinations and assessment of confidential medical information was carried out by the same clinical research fellow (a junior doctor with 5 years clinical experience), who was blinded to the results of the reference standards and the saliva and urine index test results when conducting the physical examination. Saliva and urine samples were collected and analyzed by an independent research assistant who had been trained in the handling and assessment of saliva and urine samples by a postdoctoral researcher, and who was blinded to the physical examination results. All osmolality analyses were made by a trained research assistant. Details of the patients' medical condition, history, and medication were recorded retrospectively after the reference and index test results had been established.

### *Participants*

A convenience sample of adults over 60 years of age admitted consecutively to the acute medical care unit or emergency department of Gwynedd Hospital, Bangor, UK, with any primary diagnosis and capacity to consent were enrolled between May and November 2011 during the times the investigators were available (09:00–17:00, Monday–Friday). Participant exclusion criteria included oral trauma or dental surgery within 14 days, swallowing problems, salivary gland tumors, if they were deemed too unwell by the medical staff to participate in the study, if they were assessed as not having capacity to consent, or if they had already begun any form of medical treatment or rehydration therapy (oral or intravenous). Participant flow through the study is depicted in Figure 1. All participants recruited provided fully informed written consent, and the study adhered to the Declaration of Helsinki and was approved by the North West Wales Research Ethics Committee (Ref: 11/WA/0023).

### *Assessment of Hydration Status*

#### *Reference standards*

*Blood sample collection and analysis.* Blood samples were collected from an antecubital or dorsal metacarpal vein without venestasis into one serum separation vacutainer, and 1 lithium heparin coated vacutainer (Becton Dickinson, Oxford, UK). Serum blood urea nitrogen and serum creatinine were assessed at the hospital clinical biochemistry department using an automated biochemistry analyzer (Olympus AU 2700 chemistry immuno-analyzer; Beckman Coulter, Brea, CA). The lithium heparin treated blood was centrifuged immediately upon collection at 1500 g for 10 minutes at 4°C. The plasma was aspirated and triplicate measurements of osmolality were made immediately using a freezing point depression osmometer (Model 330 MO; Advanced Instruments, Norwood, MA). Standard control solutions (290 mOsm/kg) were run through the osmometer and checked daily to ensure acceptable limits of precision ($\pm$2 mOsm/kg). The analytical coefficient of