Signs and symptoms of low-intake dehydration do not work in older care home residents - DRIE diagnostic accuracy study

Abstract

Objectives: To assess the diagnostic accuracy of commonly-used signs and symptoms of low-intake dehydration in older care home residents.

Design: Prospective diagnostic accuracy study.

Setting: 56 care homes offering residential, nursing and/or dementia care to older adults in Norfolk and Suffolk, UK.

Participants: 188 consecutively recruited care home residents aged ≥65 years, without cardiac or renal failure and not receiving palliative care. 66% female, mean age 85.7 years (SD:7.8), median MMSE score 23 (IQR:18-26).

Index tests: Over 2 hours, participants underwent double-blind assessment of 49 signs and symptoms of dehydration and measurement of serum osmolality from a venous blood sample. Signs and symptoms included skin turgor, mouth, skin and axillary dryness, capillary refill, sunken eyes, blood pressure on resting and after standing, body temperature, pulse rate, self-reported feelings of thirst and wellbeing.

Reference standard: Serum osmolality, with current dehydration defined as >300mOsm/kg, and impending dehydration ≥295mOsm/kg.

Outcome measures: For dichotomous tests, we aimed for sensitivity and specificity >70% and for continuous tests, an area under the curve (AUC) in receiver operating characteristic (ROC) plots, of >0.7.

Results: Although 20% of residents had current low-intake dehydration and a further 28% impending dehydration, none of the commonly-used clinical signs and symptoms usefully discriminated between participants with or without low-intake dehydration at either cut-off.

Conclusions/implications: This study consolidates evidence that commonly-used signs and symptoms of dehydration lack even basic levels of diagnostic accuracy in older adults, implying that many who are dehydrated are not being identified, thus compromising their health and wellbeing. We suggest these tests are withdrawn from practice and replaced with a two-stage screening process, whereby serum osmolarity, calculated from sodium, potassium, urea and glucose (assessed routinely using the Khajuria and Krahn equation) should be instituted, followed by serum osmolality measurement for those identified as high risk (calculated serum osmolarity >295mmol/L).

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Introduction

Low-intake dehydration occurs when fluid intake (drinking) is insufficient to replace obligatory fluid losses leading to intracellular dehydration characterised by hyperosmolality (>300mOsmol/kg). It is associated with increased risk of disability, hospital admission, mortality and prolonged hospital stay in older adults.[1–5] One in five older adults living in residential care has low-intake dehydration (serum osmolality >300mOsm/kg) at any one time,[6] as do 37% of older people acutely admitted to hospital.[7]

Clinically, two types of dehydration are recognised: low-intake (described above) and salt-loss dehydration resulting from excessive fluid and electrolyte loss (e.g. due to vomiting, diarrhea or bleeding) leading to a reduction in volume (hypovolaemia) and extra-cellular dehydration (where serum osmolality is either stable or lowered). These two conditions have different causes, symptoms and treatments, but low-intake dehydration is more common in older people, particularly those living in long-term care (LTC). This is because of physiological changes such as diminished thirst sensation and urinary concentrating ability, together with social and behavioral factors including reductions in oral intake resulting from reduced enjoyment of drinks, physical limitations and concerns about continence. Additionally, those with dementia may forget to drink.[8]

Whilst serum osmolality is the reference standard diagnostic test for low-intake dehydration in older people (due to its minimal intra- and inter-individual variation, direct measurement of serum concentration, association with health outcomes and robustness against being affected by renal dysfunction),[2,8–15] it is rarely measured even in acute care settings. Instead, clinical signs and symptoms are widely used

because they are believed to identify dehydration effectively and instantly, are minimally invasive, require little equipment, can be conducted by staff with little training and often without nursing or medical directive, especially in the UK where training for care staff working in long-term care is not mandatory. Commonly-used clinical signs and symptoms of low-intake dehydration include dryness of the skin, hands, armpits, eyes or oral mucosa, loss of skin elasticity, rapid pulse, hypotension, increasing confusion, lethargy, agitation, fever or urine changes (low volume, high specific gravity, dark colour). As with all valid screening and diagnostic tests, signs and symptoms of dehydration should be sensitive enough to detect low-intake dehydration when present and specific enough for clinicians to be confident that a negative test means that dehydration is absent. Whilst their validity has been assessed in younger adults and children[16–18] or as markers of hypovolaemia,[19,20] evidence for use in diagnosing low-intake dehydration in older people is lacking.[21] Where signs and symptoms have previously been assessed in older people, reference standards are no longer considered to be robust.[22–27] We recently reported that urinary measures were not useful in assessing hydration status of older adults in either community or residential settings because the concentrating abilities of the kidneys diminish with increasing age and therefore their role in maintaining fluid homeostasis also diminishes and becomes unreliable.[28,29]

At the baseline interview in the Dehydration Recognition In our Elders (DRIE) cohort study, we aimed to assess the diagnostic accuracy of non-urinary commonly-used signs and symptoms to screen for low-intake dehydration in older people living in LTC, using serum osmolality as the reference standard.

Methods

Methodology details have been published elsewhere.[6] Briefly, residents aged ≥65 years were recruited from care homes offering residential, nursing and/or dementia care in Norfolk and Suffolk (UK) between April 2012-August 2013. Residents with cardiac and/or renal failure, receiving palliative care, considered too ill, frail or anxious by their home manager were excluded. A stepped approach to recruitment ensured residents had time to consider and discuss the study before deciding for or against involvement. Interested residents were interviewed to assess their capacity to provide informed consent. Where residents were unable to demonstrate capacity, but expressed interest in participation, we contacted their consultee for written agreement (Supplementary File 1). Residents could withdraw consent, without providing reasons, at any point, either verbally or through their behavior. Examples of such behavior included closing mouth (for mouth examinations) and walking away from the interviewer.

Residents provided background information and completed the mini-mental state examination (MMSE)[30] to assess cognition. Care staff provided information on medical history, current health, health professional contacts, medications, eating and drinking abilities and current function (Barthel Index[31]). Interviews were conducted by the authors in each resident's own care home. All venepuncture and index tests took place within two hours. Researchers were blinded to serum osmolality results during index tests.

Index tests

Selection of index tests was informed by published research[16–19,21,22,24–26,32–35] and participants', advisors' and care staff suggestions. Where examinations were fully described procedures were followed, but where no detailed descriptions were found

procedures were developed by the authors. On-going standardisation meetings ensured assessment differences were noted and corrected. Levels of agreement were calculated, using kappa for categorical variables[36] and intra-class correlation coefficients (ICC) for continuous variables.[37]

Descriptions of the 49 index tests are found in the Standard Operating Procedures (SOPs, Supplementary File 1 and Figure 1). Briefly, participants were asked about their current feelings and sensations: whether their eyes and/or tongue felt dry, whether they felt thirsty, tired or 'out-of-sorts'. Researchers examined the mouth, observing tongue and mucous membranes for moistness/dryness, presence and consistency of saliva, furrowing and coating of the tongue. Lips were assessed for cracking, dryness and colour. Eyes were examined for presence of tears and whether they appeared sunken. Axillae, palms and skin on cheeks, arms and calves were assessed for dryness. Skin on the inner forearm, upper arm and base of neck were observed for crinkling and dimpling. Skin turgor, measuring time taken for a skinfold to return to normal, was assessed in two planes at four sites, twice each. Capillary refill was assessed using the index finger nail and base of the nail of the dominant hand (mean of two readings for each site) and foot vein filling was assessed on two separate veins in the same foot. Temperature was assessed using an outer ear thermometer (Braun Thermoscan, model IR4520). Pulse and blood pressure (BP) readings were taken following 20 minutes sitting, then one and three minutes after standing (where able), using the Omron M3. Weight was assessed using each care home's own scales and height estimated from ulna length.

Serum osmolality (reference standard)

Hydration status was classified using directly measured serum osmolality obtained from a non-fasting venous blood sample (antecubital vein or back-of-hand), after

participants had sat for at least five minutes. If a blood sample was not obtained at a second attempt the procedure was abandoned and participant excluded. Blood samples were collected using needle and syringe, transferred to BD vacutainers® serum separation tubes (SST), inverted several times, stored in a temperature-controlled box and delivered to the Department of Laboratory Medicine, Norfolk and Norwich University Hospitals (NNUH) Trust (Norfolk, UK) within four hours of collection. Samples were analysed on arrival. The laboratory is accredited with Clinical Pathology Accreditation (UK) Ltd., undertakes daily internal quality control and fortnightly external quality control. Serum osmolality was directly measured using depression of freezing point (Advance Instruments Model 2020, repeatability ±3mmol/kg (1 SD) in the 0-400mmol region); the laboratory coefficient of variance for serum osmolality was 0.9%.

Participants were categorised as normally hydrated (serum osmolality 275-<295mOsm/kg), having impending dehydration (295-300mOsm/kg), or current dehydration (>300mOsm/kg).[8,38] Those with serum osmolality <275mOsm/kg were excluded from this analysis.

Analyses

Our primary aim was to assess diagnostic accuracy of each index test (clinical sign or symptom) compared to serum osmolality, the reference standard, in identifying participants with or without impending or current dehydration. We aimed to identify index tests with both sensitivity and specificity >70% or area under the curve (AUC) in Receiver Operating Characteristic (ROC) plots >70%.

Thirty nine index tests (tests 1-30, 41-49, Supplementary File 1) were assessed as categorical variables and dichotomised for analysis. In Microsoft Excel, 2x2 tables were constructed to calculate sensitivity and specificity, positive and negative

likelihood ratios, positive and negative predictive values (PPV and NPV respectively), pre- and post-test probabilities and diagnostic odds ratios (DOR) for each cut-off. Ten index tests were assessed as continuous variables using Statistical Package for the Social Sciences (SPSS, version 22). Where AUC >70%, the best cut-off value for distinguishing between positive and negative test results, was assessed.[39,40] Where tests demonstrated diagnostic accuracy, we planned to compare different tests, and assess the utility of combining individually useful tests. DRIE was supported by a Steering Group and eight Advisory Groups. The Steering Group included academics, clinicians, stakeholders and members of the public (http://driestudy.appspot.com/researchers.html) and provided advice, support and guidance to researchers. The Advisory Groups consisted of care home residents or care staff and provided advice on recruitment, interpretation of findings, dissemination, conduct, future research plans and drinking and hydration care practices in care homes more widely. Some resident Advisory Group members took part in formative assessments to ensure acceptability of interview procedures and they also suggested potential index tests that were subsequently incorporated into the study. Study findings were reported back to participants, Advisory Group members, care homes and staff through newsletters and staff training.

DRIE was approved by the UK National Research Ethics Service Committee London–East Research Ethics committee (11/LO/1997) on 25/01/2012. All study procedures were in accordance with the ethical standards of the World Medical Association's Declaration of Helsinki.

Prior to commencement in January 2012, DRIE was registered with the UK Research Register for Social Care (www.researchregister.org.uk), Registration number: 122273.

Results

Of 148 care homes contacted, 67 agreed to participate. In eleven, no residents were recruited, leaving 56 care homes where at least one resident was included in DRIE. 188 residents provided data for analysis (serum osmolality and at least one index test, Figure 2), although numbers of residents undergoing each index test varied. (Supplementary File 1).

Baseline characteristics

124 (66%) participants were female, mean age 85.7 years (SD: 7.8) and median MMSE score: 23 (IQR: 18-26). 105 (54%) participants scored ≤23 on the MMSE (indicating cognitive impairment[41]) although only 61 (32%) were formally diagnosed with dementia and a further 22 (12%) were described as having dementia by care staff. The median Barthel Index score was 75 (IQR: 50-90) indicating some level of physical dependence. Almost all participants (95%) self-reported their ethnicity as 'white British', 'white Irish' or 'white Other'. 52 (28%) participants had impending dehydration (295-300mOsm/kg) and 38 (20%) were currently dehydrated (>300mOsm/kg). In the currently dehydrated group more participants were male, had diabetes and had cognitive impairment, but there were no major differences in age, Body Mass Index (BMI) or Barthel Index score (Supplementary File 1). No adverse events were reported.

Representativeness of the DRIE study population

UK 2011 Census data stated that the ratio of older women to men in residential care was 2.8:1; and people aged >85 years represented 59% of the older care home population.[42] In DRIE, 66% were female and 62% were aged >85 years. Within DRIE we found that DRIE participants were similar in sex ratio, slightly younger, with

higher BMIs than the background care home population compared with all the residents of the care homes we worked in, suggesting a slight healthy bias.[6]

Diagnostic accuracy of the index tests

None of the index tests investigated met the pre-determined criteria of both sensitivity and specificity >70% (categorical data), or AUC of the ROC plot >0.7 (continuous data) for either cut-off (≥295mOsm/kg or >300mOsm/kg). Sensitivity, specificity and DOR for the best categorical index tests (those with DOR >1) are illustrated in Table 1. The best continuous tests were skin turgor on inside forearm, capillary refill, foot vein filling and change in pulse rate, diastolic blood pressure (DBP) or pulse pressure from sitting to standing at 3 minutes. However, for none of these tests was the ROC plot area under the curve at least 0.70, and confidence intervals were wide (Figure 3).

Interrater reliability

We sent 19 disguised, duplicate serum osmolality samples to the NNUH laboratory (between June 2014 and January 2015). Duplicates were taken from the same blood draw in separate tubes with different sample numbers, dates of birth, and collection times among other samples. The mean CV for these 19 duplications was 0.58% (better than their quoted 0.9%).

Interrater reliability for the index tests was assessed using weighted kappa for categorical variables.[36] Interrater agreement was almost perfect for presence of moisture in eyes and dryness of upper arm skin, substantial for skin dimpling (inner forearm), moderate for tongue stickiness, tongue coating, tongue furrowed, axilla dampness and inner forearm skin crinkling. Kappa was not possible to calculate for two tests as all measurements were equivalent. Agreement was fair, slight or poor for the remaining 13 tests.

For continuous variables, interrater reliability was assessed for skin turgor at the four sites used, finger capillary refill and foot vein filling using the intraclass coefficient.[37] Skin turgor assessed at sternum or forearm were 'excellent', while the remaining four assessments were fair or poor.

Detailed results of all tests described can be obtained from the authors on request.

Discussion

Although 20% of older adults had current low-intake dehydration (cut-off >300mOsm/kg) and 48% had impending or current dehydration (cut-off ≥295mOsm/kg), none of the commonly-used clinical signs and symptoms usefully discriminated between participants with or without low-intake dehydration at either cut-off.

A Cochrane review evaluating diagnostic accuracy of 67 clinical signs and symptoms to detect low-intake dehydration (at both ≥295mOsm/kg and >300mOsm/kg, using serum osmolality, osmolarity or weight change over one week as reference standards in people aged ≥65 years found that only three index tests showed any ability to diagnose low-intake dehydration in individual studies.[21] These were: expressing fatigue, missing drinks between meals and bioelectrical impedance (BIA) resistance at 50kHz. All had wide confidence intervals and other studies assessing those index tests showed much poorer diagnostic accuracy, so questioning their utility. Four more recent studies have confirmed the lack of utility of clinical signs and symptoms. Fortes et al, using plasma osmolality >295mOsm/kg, demonstrated lack of diagnostic utility for pulse rate, systolic BP, dry mucous membranes, axillary dryness, skin turgor, sunken orbita, capillary refill, urine colour and urine specific gravity (USG).[43] Similar findings were reported by Hooper et al for urine colour, urine osmolality and USG using

serum osmolality >295mOsm/kg or ≥300mOsm/kg,[28,44] Tanaguchi et al for skin turgor, dry mouth and skin (using serum osmolality >292mOsm/kg)[45] and Johnson and Hahn for thirst, skin turgor, dry mucous membranes, tongue furrows and sunken orbita.[46] One study suggested that salivary osmolality may demonstrate some level of diagnostic accuracy (ROC_{AUC}=0.76) but assessment tools for the community are not available to date.[43] Evidence for utility of clinical signs and symptoms in screening for low-intake dehydration in older adults is negligible, and our assessment of signs and symptoms in DRIE confirms and extends the clear message that these tests should not be used to assess for low-intake dehydration in older adults.

We assessed “low tech” signs and symptoms that might be used cheaply and non-invasively to regularly assess for hydration status in older adults in LTC. This excluded assessment of potential tests requiring speciality equipment or laboratory facilities such as tear or salivary osmolality and BIA. During DRIE, index test acceptability and feasibility were discussed with staff and resident Advisory Groups to ensure that, should any tests be proven diagnostically useful, we knew they were also acceptable and feasible. Our study was underpowered to assess index tests with low prevalence of positive findings (e.g. ‘ropey saliva’, ‘cracked lips’). However, as dehydration prevalence was 20%, had these index tests had clinical utility, we would expect a higher occurrence rate. While at least 170 participants completed most index tests, some tests had lower participant numbers as they were included after the study commenced (on advice of care staff or our Advisory Groups), and residents with dementia or severe physical frailty were sometimes unable to answer verbal questions or to complete the interview schedule. Interrater agreement for the index tests was variable, but where two researchers who trained and worked together demonstrated low levels of agreement, this would be magnified with more assessors, suggesting that

283 when such tests are used in general clinical practice they would be unhelpful. Study
284 strengths include internal validity (DRIE's primary aim was to assess diagnostic
285 accuracy of clinical signs and symptoms), assessment of low-intake dehydration as
286 distinct from hypovolaemia,[8] the high-quality reference standard,[8,47] minimising
287 uncertainties of interpretation,[48] and the wide range of index tests examined.
288 Researchers were blinded to reference test results whilst conducting index tests, and
289 laboratory technicians measuring serum osmolality were blinded to index test results.
290 We need to be able to identify low-intake dehydration as it is common and
291 associated with death and disability in older adults.[4,7,49] Identification by health care
292 professionals currently relies on signs and symptoms and there is a reluctance to
293 discontinue current ineffective methods of assessment.[50] This study consolidates
294 evidence that commonly-used signs and symptoms lack even basic levels of
295 diagnostic accuracy and so we recommend the discontinuation of these tests as
296 indicators of low-intake dehydration, providing relevant evidence for policy-makers.[51]
297 Reliance on such tests may cause harm to older adults, as an inaccurate test falsely
298 indicating dehydration exposes older people to unnecessary interventions, but more
299 importantly, a test falsely indicating euhydration may discourage staff from providing
300 the older person with the required increased fluids. Further, the prevalence of
301 comorbidities and medication use in this population, many of which exhibit signs and
302 symptoms similar to the proposed signs of dehydration, provide additional reasons
303 why these signs and symptoms lack diagnostic utility in older people. Lack of utility of
304 currently-used tests means that many older adults who are not drinking enough are
305 not being identified, particularly those with cognitive impairment, so that their health
306 and wellbeing suffers. We suggest serum osmolality be measured to assess
307 hydration status in older adults when they are admitted to hospital or require routine

blood tests from their primary care physician. However, serum osmolality measurement is costly as laboratory tests are semi-automated, and there is concern that laboratories may be over-run with requests. Serum osmolarity calculated using the Khajuria and Krahn formula[1] from serum sodium, potassium, urea and glucose is usefully diagnostic of directly measured serum osmolality.[52,53] Instead of extensive screening using directly measured serum osmolality we could first calculate serum osmolarity from routine blood tests, encourage improved drinking where needed (where dehydration risk is high, calculated serum osmolarity >295mmol/L), then follow up those at risk with assessment of serum osmolality (directly measured by freezing point depression). This 2-stage screening would be efficient and mean only high risk older adults would need serum osmolality measured directly.[52,53]

Conclusions/Relevance

In the absence of accurate assessment of dehydration (with serum osmolarity or osmolality) increased low-intake dehydration risk should be assumed for all care home residents,[6] and attention focussed on ensuring adequate drinks are supplied and drunk.

Further research is needed to develop and validate simple minimally-invasive assessments of low-intake dehydration in older adults to replace those currently used[54]. These may include validation of tests demonstrating positive signs of being useful (such as saliva osmolality) if these can be produced in an easy-to-use, inexpensive, reproducible, minimally invasive format, or may consist of a validated series of signs and symptoms. In the absence of simple and valid tests, development

[1] Calculated osmolarity = 1.86*(Na + K) + 1.15*Glucose + Urea + 1.2*Ethanol + 14 (all measures in mmol/L).

of fully automated analysers would make routine assessment of serum osmolality in clinical settings cheaper.

Supplementary Data

1. Supplementary File 1 containing:
    - Supplementary Table 1: Baseline characteristics of DRIE population
    - DRIE Standard Operating Procedures (SOPs).
    - Supplementary Table 2: Clinical signs and symptoms, 'index tests', used in the DRIE Study, depicting number of participants providing data for each test, and reasons for missing data.

Declaration of competing interests

"All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf.

DB has declared that she received no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work."

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List of Table and Figure captions accompanying this manuscript

- **Table 1:** Sensitivity, specificity and diagnostic odds ratios (ORs, 95%CI) for dichotomous index tests with diagnostic ORs >1, assessed against serum osmolality (>300mOsm/kg cut-off)
- **Figure 1:** Screenshot of some of the standard operating procedures used to standardise the tests in DRIE
- **Figure 2:** Recruitment flow-chart for DRIE
- **Figure 3:** Receiver Operating Curves (ROC) for dehydration (>300mOsm/kg cut-off) for the most promising continuous index tests in each group