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Dehydration among the Elderly: A Comparison between Nine Different Clinical and Metabolic Criteria

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ABSTRACT

Background: Dehydration, as a common problem in older adults, plays a significant role in morbidity and mortality. The elderly are more susceptible to dehydration and fluid deficiency due to age-related factors. There is not much literature concerning fluid intake in older adults. This study aims to investigate fluid intake and dehydration prevalence in older people and compare the accuracy of potential markers in the detection of dehydration. **Methods:** This cross-sectional study was done on 127 old people (48 males and 79 females) selected from a nursing home in Shiraz, Iran. Socioeconomic status was assessed via interview. Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), urine specific gravity (USG), urine color (UC) and bioelectrical impedance analysis (BIA), extracellular water (ECW), intracellular water (ICW), and total body water (TBW) were measured. The fluid intakes were recorded using a beverage and fluid intake questionnaire. Total fluid intakes were compared using two fluid intake guidelines (European guidelines and US guidelines) as well. Furthermore, anthropometric indices were measured. **Results:** The mean age of participants was 73.01± 5.70 year. Fluid intake was 2.32 ± 0.48 liter/day. Based on urine specific gravity (USG) (>1.020) and SBP (SBP < 100 mmHg), 9.4% and 14.2% of the participants were dehydrated respectively. Among all hydration criteria, ECW had the highest potential for detection which identified 72.4% of participants as dehydrated. Among fluid intake guidelines, US guidelines were the best in dehydration diagnosis (112 individuals out of 127). **Conclusions:** Although urinary markers and physical indexes (SBP and HR) could not be used to determine hydration status, BIA measurements, especially ECW, have the potential to detect dehydration. In addition, daily fluid intakes are still practical for assessment of hydration status.

Keywords: *Elderly; Dehydration; Fluid intake; Cross-sectional*

Introduction

Dehydration as negative fluid balance, is the most common fluid disorder in older adults (Warren *et al.*, 1994) and is associated with life-threatening consequences among them (Weinberg and Minaker, 1995). Older adults are more susceptible to dehydration because of

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physiological problems associated with aging including age-related changes in thirst response and kidney functions (Phillips *et al.*, 1984). Serious conditions documented as a result of dehydration include acute confusion, urinary tract infections, delirium, renal failure, and constipation (Bennett *et al.*, 2004, Mentes *et al.*, 1999). It is also revealed that compared to well-hydrated subjects, dehydrated older patients had about a 40% increased higher risk of mortality along with two-fold increased risk of new disability over the next 4 years (Stookey *et al.*, 2004a).

There is no "gold standard" marker to define dehydration (Armstrong, 2007); however, blood biochemistry analyses including plasma osmolality, electrolytes and blood urea nitrogen to creatinine ratio has been used to identify dehydration in high sensitivity clinical settings (McGee *et al.*, 1999b, Thomas *et al.*, 2008). As blood sampling is an invasive and time consuming method for diagnosis of dehydration, physicians might use a variety of simple screening tools in the first step (Vivanti *et al.*, 2010, Vivanti *et al.*, 2008). Fluid intake (Agostoni *et al.*, 2010), orthostatic blood pressure changes (Chassagne *et al.*, 2006), urinary parameters [urine color (UC) and urine specific gravity (USG)] (Wakefield *et al.*, 2002) and bioelectrical impedance analysis (BIA) (Kafri *et al.*, 2013) are widely selected for the initial diagnosis. Nevertheless, these screening methods are supposed to be poor in specificity for the diagnosis of dehydration (Eaton *et al.*, 1994, Shimizu *et al.*, 2012). Several investigations have been accomplished to find the best simple, non-invasive indicator of dehydration. For instance, a study was done by Kafri (Kafri *et al.*, 2013) on 27 stroke patients aged 46-92 year to evaluate the diagnostic accuracy of multi-frequency bioelectrical impedance analysis (MF-BIA) against clinical markers. Findings revealed that diagnostic accuracy of MF-BIA was poor and only the total body water (TBW) cut-off at 46% might be consistent with current dehydration. Fortes (Fortes *et al.*, 2015) did a study on 130 men and women aged over 65 admitted to the hospital to undergo a hydration status assessment before any primary diagnosis. All physical markers of dehydration assessment were poorly sensitive. Only low systolic blood pressure (SBP) was considered a potential utility for the primary diagnosis of dehydration. Neither UC nor USG could discriminate hydration status. The study was done by Hooper (Hooper *et al.*, 2016) on people aged over 65 year; it reported that although USG, UC, and urine osmolality have been widely used for detecting dehydration in older adults, neither USG nor any other urinary markers were useful for detection of water-loss dehydration.

A limited number of studies tried to assess dehydration status based on several biochemical and clinical criteria. Furthermore, no studies have been conducted in the Middle East regarding the prevalence of dehydration in the elderly population; therefore, the authors tried to report and compare the prevalence of dehydration using different methods including BIA, hear rate (HR), blood pressure (BP), UC, USG and fluid intake in a sample of the elderly living in Shiraz, Iran.

Materials and Methods

Study design and participants: This cross-sectional study was conducted on elderly people in an outpatient center, which is the only daycare center for non-institutionalized elderly people in Shiraz, Iran. Participants recruited in this study were 117 older adults aged 65 years and above (66-93), who were in good mental health, with no disability or physical deformation affecting anthropometric measurements; they were able to communicate well. In addition, the authors excluded the participants with the following characteristics which may affect hydration status: chronic renal failure, oral disorders, fatal coronary heart disease, stroke, and gastrointestinal diseases. Participants' recruitment was done from June 2015 to November 2015.

Measurements: Participants were asked to provide information on socio-demographic characteristics including: age, marital status, job status, education, number of children, and smoking through face to face interviews.

HR, BP, UC, USG, BIA, total body water

(TBW), intracellular water (ICW) and extracellular water (ECW) were determined. Tachycardia (resting HR >100 bpm), low resting SBP <100 mmHg, USG > 1.035, UC > 4, TBW < 47%, ICW < 27%, and ECW < 20% as a percentage of body weight were defined as cut offs for dehydration (**Table 1**).

Weight was measured by digital scales (Seca 881, Germany) to the nearest 0.1 kg in light clothing without shoes. Height was measured without shoes using a stadiometer (Seca 214 portable stadiometer) to the nearest 0.1 cm. Waist circumference (WC) was measured using an upstretched tape measure without any pressure, in a horizontal plane at the midpoint between the inferior margin of the last rib and the superior iliac crest. Body mass index (BMI) was calculated as weight (kg)/height (m)^2. Body composition was recorded by a portable BIA device (In Body S10®, In Body Corp., Seoul, South Korea). Participants were asked to remove any jewelry and lying in supine position with their arms and legs spread out.

Early morning urine samples were collected in sterile bottles without any preservatives. Small aliquots of urine were used for USG and UC analysis. USG was recorded using a handheld refractometer (Pars Azmoon, Tehran, Iran), which was calibrated from 1.00 to 1.035 against liquid preparations of known relative density (mass/volume). UC was analyzed in a well-lighted room against a standardized 4-point color chart (Pars Azmoon, Tehran, Iran). Triplicate analysis of 4 specimens (12 aliquots) was performed in one day to test observations' reliability for UC.

BP was measured twice by physicians while the participants were in a sitting position after a 5-minute rest, with the arm cuff at the heart level using a mercury sphygmomanometer. Heart rate was measured in triplicate in resting position using a digital automatic device (Microlife, model BP 3AC1-1 PC, Microlife AG, Widnau, Switzerland) which was validated at resting position for hemodynamic measurements according to the British Association of Cardiology (Cuckson *et al.*, 2002). The average recorded measurements were reported for both BP and HR.

A beverage and fluid intake questionnaire was used to assess the total fluid intakes. The validity and reliability of the questionnaire have been approved (Hedrick *et al.*, 2010).

Ethical considerations: All the procedures and aims of the study were explained to the participants, and then, written consents were signed by them.

Data analysis: Data were summarized, processed, and analyzed using SPSS version 19. Frequency, mean and standard deviations were measured and reported. The Chi-square test was used for reporting gender differences. Mean of dehydration indices were compared between different criteria using analysis of variance (ANOVA).

Results

A summary of demographic and general characteristics of total participants are provided in **Table 2.** The educational degree of 62 participants was lower than high school diploma. About 40% of the participants mentioned that they had physical inactivity, and more than 60% of the individuals were married. With respect to job status, the majority of participants were housekeepers (44.9%) and retired (29.1%). Nine different criteria (fluid intakes based on European and American guidelines, HR, SBP, USG, UC, TBW, ICW and ECW as a percentage of body weight) were used to assess hydration status individually. There were no significant differences in HR (P = 0.48), SBP (P = 0.24) and total fluid intake (P = 0.49) between men and women. Values for TBW, ICW and ECW were significantly different between males and females (P < 0.05).

Detailed information on total fluid and beverage intake are explained in **Table 3.** The total fluid intake was 2.32±0.48 lit/day for all the subjects. The total fluid intake in females (2.34±0.49 lit/day) was acceptable based on European not US guidelines. Total fluid intake for men was 2.20±0.47 lit/day, which was lower than suggested amounts by European or US guidelines (2.5 and 3.7 lit/day, respectively).

Results of hydration status are shown in **Table**

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4. Significant differences were seen between normal hydrated and dehydrated participants for all markers. Two criteria were used based on fluid intake (European and USA guidelines). Since the cut-off points for USA Panel on Dietary Reference intake were higher than European guidelines (< 3.7 and < 2.7 l/day vs < 2.5 and < 2 l/day), more participants were categorized as dehydrated (88.9%) in comparison to European guidelines (40.5%).

HR and SBP, as physical indices of dehydration, had similar and poor potential for detecting of dehydration. Based on HR and SBP, 84.3% and 85.8% were categorized as normally hydrated respectively. Among BIA measurements, ECW and ICW had the highest and lowest diagnostic potential to detect dehydrated subjects (72.4% and 39.4%, respectively). The BIA markers (TBW, ICW and ECW) were higher in females in comparison to males regarding potential detection. Both urinary markers (UC and USG) had poor diagnostic properties. Nevertheless, they identify male-dehydrated individuals rather than female ones.

Table 1. Diagnostic criteria to assess dehydration among elderly people.

Test	description	Cut-off reasoning
Fluid intake	Fluid intake (fluid from food and drinks) Very low: < 1.7 l in men, < 1.3 L in women Low: 1.7 to < 2.7 l in men, 1.3 to < 2.0 L in women Moderate: 2.7 to < 3.7 l in men, 2.0 to <2.7 L in women High: ≥ 3.7 l in men, ≥ 2.7 l in women	European guidance, (Hooper *et al.*, 2015) suggests that men need 2.5 l/d of fluid (overall, from food and drinks), and women need 2.0 l/d. The US Panel on Dietary Reference Intakes (Institute of medicine of the national academies, 2005) suggests that men need 3.7 l/d and women 2.7 l/d of fluid from all sources. The authors set cut offs to reflect the range of fluid intakes above and below these levels
Heart rate	Heart rates below 60 bpm are called bradycardia, and over 100 bpm are called tachycardia.	Resting HR > 100 bpm (Fortes *et al.*, 2015)
Low systolic blood pressure	< 100 mmHg versus ≥ 100 mmHg	< 100 mmHg (Fortes *et al.*, 2015)
Urine specific gravity	Various normal ranges for USG are suggested including 1.006 to 1.020 (Bossingham *et al.*, 2005)	≥ 1.035 Armstrong suggested that > 1.035 is consistent with frank dehydration (Armstrong *et al.*, 1998)
Urine color	Urine color as assessed on the Armstrong color chart	> 4 (Armstrong *et al.*, 1998)
Total body water as % of total body weight by BIA	< 47% versus ≥ 47%	< 47% Cut-offs chosen based on data published (Kafri *et al.*, 2013)
Intracellular water as % of total body weight by BIA	< 27% versus ≥ 27%	< 27% Cut-offs chosen based on data published (Kafri *et al.*, 2013)
Extracellular water as a % of total body weight by BIA	< 20% versus ≥ 20%	< 20% Cut-offs chosen based on data published (Kafri *et al.*, 2013)

Table 2. General characteristics of the participants

Variables	Male (n = 48)	Female (n = 79)	Total (n = 127)	P-value[a]
Age (year)	75.10 ± 7.02[b]	71.74 ± 4.32	73.01 ± 5.01	0.004
Weight (kg)	63.85 ± 8.07	67.04 ± 11.71	65.84 ± 10.56	0.072
Waist circumference (cm)	89.16 ± 10.97	89.73 ± 13.32	95.11 ± 13.28	<0.001
Body mass index (kg/m^2)	23.49 ± 2.85	28.30 ± 4.93	26.48 ± 4.86	<0.001
Hip circumference (cm)	96.93 ± 6.90	107.59 ± 12.59	103.5 ± 11.95	<0.001
Heart rate	79.95 ± 17.02	77.96 ± 12.86	78.71 ± 14.54	0.486
Systolic blood pressure (mmHg)	12.31 ± 2.31	12.78 ± 1.99	12.60 ± 2.12	0.243
Diastolic blood pressure (mmHg)	7.45 ± 1.46	7.41 ± 0.98	7.42 ± 1.18	0.872
Total body water (l)	34.47 ± 4.04	28.33 ± 3.48	30.65 ± 4.74	<0.001
Intercellular water (l)	21.14 ± 2.56	17.21± 2.11	18.69 ± 2.98	<0.001
Extracellular water (l)	13.30 ± 1.49	11.03 ± 1.31	11.90 ± 1.77	<0.001
Body fat percent	25.83 ± 7.43	40.35 ± 7.57	34.86 ± 10.30	<0.001
Education status	**N (%)**	**N (%)**	**N (%)**	**P-value[c]**
Illiterate	5 (10.4)	10 (12.7)	15 (11.8)	0.081
Lower than high school diploma	18 (37.5)	44 (55.7)	62 (48.8)	
Higher than high school diploma	13 (27.1)	17 (21.5)	30 (23.6)	
Academic education	12 (25)	8 (10.1)	20 (15.7)	
Marital status				
Single	6 (12.5)	37 (46.8)	43 (33.9)	<0.001
Married	42 (87.5)	42 (53.2)	84 (66.1)	
Job				
Housekeeper	1 (2.1)	56 (70.9)	57 (44.9)	<0.001
Self-employed	15 (31.3)	3 (3.8)	18 (14.2)	
Retired	19 (39.6)	18 (22.8)	37 (29.1)	
Government employee	13 (27.1)	2 (2.5)	15 (11.8)	
Physical activity status				
Sedentary	17 (35.4)	35 (44.3)	52 (40.9)	0.178
Low activity	18 (37.5)	33 (41.8)	51 (40.2)	
Active	13 (27.1)	11 (13.9)	24 (18.9)	

[a]: Independent sample t-test ; [b]: Mean ± SD ; [c]: Chi-square test.

Table 3. Total fluid (mean±SD)and beverage intake of participants.

Type of fluids	Males (n = 48)	Females (n = 79)	Total (n = 127)	P-value[a]
Water (ml/day)	1473.95 ± 343.01	1528.48 ± 353.52	1507.87 ± 349.22	<0.001
100 % fruit juice (ml/day)	104.16 ± 103.81	122.60 ± 195.93	115.63 ± 166.93	<0.001
100 % vegetable juice (ml/day)	15.32 ± 15.45	36.61 ± 90.72	28.57 ± 72.74	<0.001
Syrup (ml/day)	60.93 ± 48.62	56.32 ± 57.27	58.07 ± 54.01	<0.001
Whole milk (ml/day)	4.68 ± 23.89	15.05 ± 58.30	11.13 ± 48.40	<0.001
Reduced and low fat milk (ml/day)	143.63 ± 99.14	144.23 ± 104.40	144.01 ± 102.05	<0.001
Soft drinks (ml/day)	160.04 ± 112.57	141.18 ± 102.18	148.31 ± 106.18	<0.001
Coffee or tea alone (ml/day)	122.91 ± 97.62	92.22 ± 84.90	103.82 ± 90.77	<0.001
Sweetened tea (ml/day)	183.70 ± 128.93	186.21 ± 147.63	185.26 ± 140.34	<0.001
Sweetened coffee (ml/day)	29.85 ± 7.29	35.23 ± 7.77	33.18 ± 7.59	<0.001
Total fluid intake (l/day)	2.28 ± 0.47	2.34 ± 0.49	2.32 ± 0.48	<0.001

[a]: Independent sample t-test.

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Table 4. Results of hydration status among participants based on different criteria.

Test indicator	Normal hydration			Dehydration			P value[a]
	Male	Female	Total	Male	Female	Total	
Fluid overall European guidelines	15 (31.1)[b]	60 (76.9)	75 (59.5)	33(68.8)	18 (23.1)	51 (40.5)	<0.001
Fluid overall United state guidelines	1 (2.1)	13 (16.6)	14 (11.1)	47 (97.9)	65 (83.3)	112 (88.9)	0.017
Heart rate	35 (72.9)	72 (91.1)	107 (84.3)	13 (27.1)	7 (8.9)	20 (15.7)	0.011
Systolic blood pressure	36 (75.0)	73 (92.4)	109 (85.8)	12 (25)	6 (7.6)	18 (14.2)	0.009
Total body water	44 (91.7)	13 (16.5)	57 (44.9)	4 (8.3)	66 (53.5)	70 (55.1)	<0.001
Intracellular water	47 (97.9)	30 (38)	77 (60.6)	1 (2.1)	49 (62.0)	50 (39.4)	<0.001
Extracellular water	32 (66.7)	3 (3.8)	35 (27.6)	16 (33.3)	76 (96.2)	92 (72.4)	<0.001
Urine specific gravity	40 (83.3)	75 (94.9)	115 (90.6)	8 (16.7)	4 (5.1)	12 (9.4)	0.040
Urine color	23 (47.9)	62 (78.5)	85 (66.9)	25 (52.1)	17 (21.5)	42 (33.1)	0.001

[a]: Chi-square test; [b]: N (%).

Discussion

Dehydration in older adults is among the major causes of hospitalization, resulting in poor functional status, morbidity, and mortality during clinical care (Rowat *et al.*, 2012, Stookey *et al.*, 2004b). To reduce the burden of healthcare, early analysis of hydration status is more important than prevention (Warren *et al.*, 1994, Xiao *et al.*, 2004). Thus, this cross-sectional study sought to investigate the diagnostic accuracy of routinely used physical (heart rate, SBP, total fluid intake, TBW, ICW and ECW) and metabolic (USG and UC) indices, and compare their sensitivity and accuracy in the identification of dehydration. In fact, in the current study, some of the physical and metabolic indexes used to detect hydration status were compared. HR, SBP and urinary markers showed poor diagnostic accuracy. However, fluid intake guidelines, especially US guidelines, are still appropriate tools for diagnosing dehydration. In addition, ECW demonstrated the best potential accuracy among the physical markers.

The authors compared two fluid intake guidelines (European guidelines and US guidelines), and found that US guidelines entail more administrative power than European ones. Based on the results, HR and SBP could not be used as detector markers. While BIA measurements especially ECW had the highest capacity for detecting dehydration. Urinary markers also showed poor detection quality.

In a study done by Fortes (Fortes *et al.*, 2015) , 7 physical signs of dehydration (SBP<100 mm Hg) including dry mucous membrane, dry axilla, poor skin turgor, sunken eyes, and long capillary refill time (>2 seconds)] as well as urinary markers (USG and UC) were compared to investigate their diagnostic accuracy. They considered plasma osmolality as the standard reference of hydration. All physical signs had poor sensitivity (from 0% to 44%) regarding dehydration detection. Moreover, both urinary indices (USG and UC) showed poor sensitivity; this supported the findings of this study. However, they reported low SBP to have the only potential utility for diagnosis of dehydration; however, this study found it to be a poor index.

According to the results of the current research, urinary markers (USG and UC) showed little utility for determining dehydration in the elderly. As the evidence supported, clinical physical signs were not appropriate markers to diagnose dehydration when applied to older adults due to a wide range of factors. For instance, loss of skin elasticity advances with aging (McGough-Csarny and Kopac, 1998), use of anticholinergic medications can result in dry mouth mucosa (Turner and Ship, 2007), and use of antihypertensive drugs may affect blood pressure (Gueyffier *et al.*, 1999, McGee *et al.*, 1999a). Although urinary markers have been suggested as valid methods to assess acute hydration changes in young adults, neither USG nor UC had appropriate

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accuracy to determine hydration status in the current study. These findings may result from many types of medication prescribed for older adults or decreased renal function, which progress with aging (Coresh *et al.*, 2003, Lindeman, 1993). Similarly, previous literature showed that urinary indices were poor markers of hydration status in older adults (Rowat *et al.*, 2011), in critically ill patients (Fletcher *et al.*, 1999), and in children with gastroenteritis (Steiner *et al.*, 2007). In addition, the results of a study done by Rowat (Rowat *et al.*, 2011) did not support the use of urinary indices as an early indicator of dehydration. In their study, the diagnostic accuracy of urinary markers was compared with routine blood urea/creatinine ratios, which is a standard blood indicator of hydration status. In another study, the diagnostic accuracy of BIA measurements was evaluated against serum osmolality and osmolality as reference standards. Only TBW cut-off < 46% was consistent with dehydration (serum osmolality > 300 mOsm/kg). Thus, in contrast with the findings of this study, BIA measurements were not effective for diagnosing dehydration (Kafri *et al.*, 2013) . In a study in Europe, the accuracy of potential urinary markers of dehydration diagnosis was compared in older adults. In this study USG, UC, and urine osmolality were compared to serum osmolality as a reference test. The results of the study did not support the accuracy of USG, UC, and urine osmolality (Hooper *et al.*, 2016). Rosler *et al.* conducted a comparison study between clinical and bio-impedance analysis of hydration status. Concordance between the results of clinical judgment and BIA measurements was only 43.7% (Rösler *et al.*, 2010). BIA indicators showed the highest diagnosis capacity versus clinical and urinary markers. Chevront *et al.* compared various biological markers (plasma osmolality, BMI and USG) for their efficiency in determining hydration status. Finally, they concluded that plasma osmolality was the only practical marker for dehydration diagnosis (Cheuvront *et al.*, 2010).

There were some limitations in this study. Due to financial limitations plasma osmolality of individuals as the gold standard marker of dehydration could not be assessed. Therefore, the authors could not compare the diagnostic accuracy of hydration markers with a gold standard index. The small sample size was another limitation of the current study. Furthermore, the participants' medication was not recorded in the current study, and a fluid intake questionnaire was used, which is not validated for Iranian individuals. A particular strength of research was that 9 markers of dehydration were assessed simultaneously; therefore, their accuracy was compared to choose the best appropriate index.

Conclusions

The elderly are more susceptible to dehydration due to age-related complications such as kidney dysfunction and the change in thirst responses. Early diagnosis of dehydration could diminish burden on healthcare systems and prevent the following complications. Thus, there is a need for simple, inexpensive, and efficient tools for the evaluation of dehydration in older adults. Findings revealed that daily fluid intakes are still practical for assessment of hydration status. It was also found that US guidelines are more inclined to lower intake of fluids rather than European guidelines (88.9 % diagnosis of dehydration based on US guidelines in comparison to 40.5 % for European guidelines). Moreover, among BIA measurements, ECW showed the best accuracy for identifying dehydration. Neither urinary markers (USG, UC) nor HR and SBP could appropriately determine dehydration status.

Authors' Contribution

Raeisi-Dehkordi H performed the study design. Raeisi-Dehkordi H and Shekarkhand SH collected the data. Raeisi-Dehkordi H performed the statistical analysis. Raeisi-Dehkordi H wrote the first draft of the paper. Shiva F critically reviewed the paper.

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Conflicts of interest

The authors declared no conflict of interest.

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