Nutr Hosp 2016; 33(Supl. 3):13-18 ISSN 0212-1611 - CODEN NUHOEQ S.V.R. 318

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Nutrición Hospitalaria

Urinary hydration biomarkers and water sources in free-living elderly

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Abstract

Introduction: Accurate estimates of water intake and hydration status in populations are essential to identify populations at risk of dehydration and define strategies to improve standards of water intake.

Objective: To evaluate the hydration status and the contribution of food and beverages to the total water intake in a sample of free-living physically active Portuguese elderly.

Methods: A sample of 74 individuals (28 men), aged 60 to 83 years, were included in this study. A 24 h urine sample was collected; 24 h urine volume and osmolality were quantified in order to estimate the free water reserve (FWR) used to assess the hydration status. A 24 h food recall corresponding to the day of urine collection was obtained. Food and beverages were grouped according to their nutritional composition, namely water content. The contribution of those groups to total water intake and its association with the hydration status were estimated. Urinary markers and food groups' contribution to total water intake were compared between sexes and according to the median FWR, using the t-test and Mann Whitney test.

Results: Less than 10% of the participants were classified as hypohydrated/at hypohydration risk. Water from food was nearly half of the total water intake (47% in females and 48% in males, $p = 0.757$). "Water" (22%) and "foods with reduced water content" (19%) were the groups that contributed the most to the total water intake in women and men, respectively. In men, the contribution of "alcoholic beverages" was significantly higher than that of women (10.5% *vs* 1.7%, $p < 0.001$).

Conclusions: Even though most of the study participants were classified as euhydrated, the contribution of water-rich and nutritionally dense food, and non-alcoholic beverages, particularly in men, should be promoted.

Key words: Hydration status. Water sources. Elderly. Free water reserve.

INTRODUCTION

Water is an essential element for the functioning of the body (1), thus maintaining an adequate state of hydration is an important determinant of human health (2). Water is required for a wide range of physiological functions, such as metabolic transport, temperature regulation, maintenance of circulatory volume, cellular waste disposal, and as a solvent in organic reactions (3).

The human body has several mechanisms to regulate water content, which operate simultaneously to maintain the balance between gains and losses. This adjustment depends on hypothalamic mechanisms to control thirst, antidiuretic hormones, the kidneys ability to retain or excrete water as well as water loss by respiration and perspiration (4).

Although the elderly present fluid intake needs similar to those described in young adults, older individuals are exposed to a higher risk of dehydration when compared to younger adults. In fact, the aging process is associated with various physiological changes, including the decrease in perception of thirst and consequent insufficient water intake, loss of muscle mass and changes in renal function (5-9). Older individuals may also show an increased loss of liquids via infection, dementia, diuretics, etc. (2,10). Furthermore, according to Godfrey et al. (2012), some factors can contribute to reducing water intake in older people, such as fatigue, lack of pleasure associated with eating and the fear associated with urine incontinence or the need to urinate frequently (11).

Even mild dehydration is slight, defined by a loss of 1% to 2% of body weight, it affects physical performance and cognition, particularly in the elderly and children (12,13). For the elderly, dehydration is the most common electrolyte disorder and is a common cause of hospitalization (7,8).

The consequences of acute dehydration are well described. It evolves over a short period and can trigger low blood pressure, loss of consciousness, seizures, coma and even death if water loss reaches about 8% (14). In contrast, although associated with an increased risk of diseases such as urolithiasis, constipation, urinary tract infections, headaches and kidney dysfunction (15), mild chronic dehydration has not been sufficiently studied from a long-term perspective.

Although there is no universally accepted method for measuring hydration status (HS), various procedures, such as the

Gonçalves A, Silva J, Carvalho J, Moreira P, Padrão P. Urinary hydration biomarkers and water sources in free-living elderly. Nutr Hosp 2016;33(Supl. 3):13-18

DOI:http://dx.dpi.org/10.20960/nh.311

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evaluation of fluid losses by variation of body weight, blood markers, urinary markers, electrical bioimpedance (16) and physical signs, have been used (17). Some authors argue, however, that the free water reserve (FWR) is the most appropriate marker to characterize hydration of individuals in a 24 hour period (18,19).

Analyzing water intake is a complex process and is often omitted in nutritional intake evaluation studies. However, accurate estimates of water intake and HS are essential to identifying populations at risk of dehydration (20) and in defining strategies to improve patterns of water intake.

OBJECTIVES

The aim of the present study is to evaluate the hydration status and the contribution of food and beverages to the total water intake in a sample of free-living physically active elderly.

METHODS

STUDY DESIGN

This cross-sectional study was approved by the Ethics Committee of the University of Porto and the National Data Protection Commission. At the first meeting, all participants received a full explanation on the purpose of the study and all related procedures. Informed consent was obtained from all participants and confidentiality was guaranteed. The study took place between November 2012 and April 2013.

PARTICIPANTS

The study sample included individuals taking part in a physical activity program at the Faculty of Sport, University of Porto (FADEUP), and users of a day center. The sample was selected based on convenience. We invited, by telephone and in-person, 148 people with a minimum age of 60, in stable posture and functional autonomy, who frequented those institutions. None of the participants were institutionalized at the time of data collection.

From the 148 invited elderly, 113 (78%) agreed to participate (38 men and 75 women), but 39 (10 men) were excluded due to daily diuretic therapy, cognitive impairment or incomplete urine collection, according to a creatinine ratio (described in detail below).

For practical reasons throughout this work, the term “elderly” was adopted to describe participants that were at least 60 years of age, in contrast to the more common meaning used to nominate individuals from the age of 65 (21).

A sample of 74 individuals (28 men), between 60 and 83 years of age, were included in this study.

DATA COLLECTION

A structured questionnaire was used to collect socio-demographic (age, sex and education), and clinical (medical history and current medication) data. The IPAQ - International Physical Activity Questionnaire, validated in Portuguese adults (22) was used to assess physical activity and to evaluate the cognitive state, the MMSE – Mini-Mental State Examination (23) was applied.

The collection of anthropometric data (weight and height) was performed according to standard procedures (24). Weight was measured using a digital balance (SECA®; range 0.1-150 kg; precision 100 g) and height was obtained using a stadiometer (SECA®; range 70-205 cm; precision 1 mm). Body mass index (BMI) was calculated using the formula: weight/height^2. Participants were categorized according to the reference values of the World Health Organization (WHO) (25) as underweight (< 18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2) or obese (≥ 30 kg/m^2). Due to the small number of participants classified as “underweight” (n = 2) in this study, the decision was made to aggregate the two lower BMI classes, for statistical analysis.

A 24-hour urine sample was collected, after having distributed flyers illustrating the instructions inherent in the process of collecting urine and then reinforced the explanation orally. In addition, telephone contact was offered at any time of the day, in order to clarify questions regarding urine collection. Thus, all participants were instructed to discard the first urine in the morning and to collect all the urine over the following 24 hours, including the first urine of the next morning. The 24-hour urine collection was stored in individual containers with preserver, and participants were asked to keep the container refrigerated until delivery time on the day that urine collection was concluded. All samples were analyzed at a certified laboratory (LabMED) and the following urinary markers were quantified: urine volume (ml), urinary creatinine (mg/day) and urine osmolality (mOsm/kg) for 24 hours. Urinary creatinine was measured by the Jaffe method. The completeness of the samples was verified by analysis of creatinine excretion in relation to body weight, using the formula: coefficient of creatinine = creatinine (mg/day)/body weight (kg). The presence of coefficients between 14.4 and 33.6 in men and between 10.8 and 25.2 in women was considered as an acceptable window of 24 urine samples (26).

The HS was evaluated based on the parameter FWR (ml/24 h) (15,18,27-30), calculated by subtracting 24 hour urine volume to obligatory urine volume (solutes in urine 24 h [mOsm/day]/ [830-3.4] x [age-20]) and allows for the classification of the 24 hour hydration status (euhydrated *vs* hypohydrated subjects or at risk of hypohydration [27]).

Additionally, a 24-hour food recall was applied, corresponding to the urine collection day. The Portuguese Food guide was used for the estimation of ingested portions (31). For the conversion of food into nutrients, including the contribution of water from food, we used the Food Processor Plus® (ESHA Research, USA). Although this software uses the Table of Food Composition of the

United States Department of Agriculture (32), containing raw and/or processed foods, for this work the nutritional content of food or typical Portuguese culinary dishes consumed by the sample in this study has been added to that database, according to the table of Portuguese food composition (33). For industrial products, when it was referenced food brands, nutritional information described on the label of the package was used.

Food and beverage groups were created (Table I) to estimate the contribution of food groups to total water intake and its association with the hydration status.

STATISTICAL ANALYSIS

Data was analyzed using the statistical program IBM SPSS® Inc. (version 21.0) for Microsoft Windows®. The Kolmogorov-Smirnov test was used to test the normality of continuous variables. Descriptive statistics was used to characterize the sample. Categorical variables were expressed as absolute and relative frequencies, and continuous variables as mean and standard deviations (mean ± standard deviation). The Student's t-test for independent samples and the Mann-Whitney test were used to compare cardinal variables according to their normality. Chi-squared test was also used to compare proportions. It was considered as statistically significant at $p < 0.05$.

Table I. Food and beverage groups created to estimate the contribution of food groups to total water intake

Food groups	Food included
Dairy	Milk and yogurt
Vegetables	Soup and vegetables: raw, cooked, canned and frozen
Fruits	Fresh fruit and canned (no syrup)
Coffee, barley	Coffee and barley
Other drinks	Soft drinks including light versions/diet/zero (carbonated and non-carbonated), drinks with sugar (lemonade, iced tea), flavored drinks, sports drinks, juices and soy beverages
Tea, infusions	Tea and infusions
Water	Mineral or spring water, with or without gas, bottled or not, and tap water
Alcoholic beverages	Wine, sangria, beer, spirits
Other foods	Meat, fish, eggs, cereal, pastries, potatoes, legumes, fats and cheese

RESULTS

The general characteristics of the final sample are given in table II. Participants were mainly female (62.2%) and 70.2 ± 5.99 years of age on average. About half of the sample (56.5% women and 46.4% of men) reported having 4 years, at most, of schooling and 47.8% of women and 53.6% of men had BMI values between 25.0-29.9 kg/m^2. The majority of the sample reported moderate (30.4% of women and 39.3% of men) and high (54.3% of women and 39.3% of men) levels of physical activity. Approximately half of the participants reported having hypertension (57.8% female and 48.1% male) and hypercholesterolemia (51.1% female and 51.9% male). Kidney failure was reported by a 5.5% of the sample.

Most of the participants were classified as being euhydrated (91.9%). It was found that urinary parameters analyzed did not differ significantly between sexes, except for the obligatory urine volume, which was higher in men (1251.0 ml *vs* 1013.2 ml in women, $p = 0.001$).

Table II also describes the characteristics of the participants according to HS (below and above the median FWR), by sex. In men, age, education, level of physical activity and weight status were not significantly associated with HS. In turn, women above the median FWR showed, on average, higher age (72.8 *vs* 67.9 years, $p = 0.010$). All urinary parameters were significantly associated with hydration status, except for obligatory urine volume, in both sexes. Osmolality was lower in women and men below the median FWR (292.6 ml *vs* 512.9 ml, $p < 0.001$ ml *vs* 573.3 and 334.7 ml, $p < 0.001$, respectively, in women and men). On the other hand, the total urine volume was significantly higher in "better hydrated" participants (2,299.1 *vs* 1,364.8 ml, $p < 0.001$ *vs* 1,457.9 and 2,507.1 ml ml, $p < 0.001$, respectively, in women and men), similar to FWR (1,296.8 ml *vs* 340.7 ml, $p < 0.001$ and 1,231.1 ml *vs* 231.9 ml, $p < 0.001$, respectively, in women and men).

Total water intake was significantly higher in women who were above the median FWR compared to those who were below the median (2,353.3 *vs* 1,884.3 ml, $p = 0.018$), with no significant difference in men (1,999.4 *vs* 2,417.1 ml, $p = 0.198$). The contribution of different groups of food and beverages for total water intake did not differ according to the HS.

Total water intake, considering food and beverages, was 2,153 ml on average, with no differences between sexes The contribution of water from various groups of food and beverages did not differ between sexes either, except for "alcoholic beverages", with a significantly higher contribution in men (10.5% *vs* 1.7%, $p < 0.001$) (Table II).

As shown in figure 1, the contribution of water from food was approximately half of the total intake of water (47% in females and 48% in males, $p = 0.757$). In women, the contribution of "non-alcoholic beverages" was significantly higher than that of men (51% *vs* 42%, $p = 0.029$).

On figure 2 we can observe the contribution of water intake by groups of food and beverages, by sex. "Water" (22%) and "foods with reduced water content" (19%) were the groups that contributed most to the total water intake in women and men, respectively.

Table II. Characteristics of participants according to sex and hydration status

		Women (n = 46)	Men (n = 28)	p	Women (n = 46)			Men (n = 28)		
					Below the median of FWR (n = 23)	Above the median of FWR (n = 23)	p	Below the median of FWR (n = 14)	Above the median of FWR (n = 14)	p
Age, mean ± SD	years	70.3 ± 6.63	70.0 ± 4.87	0.803	67.9 ± 5.81	72.8 ± 6.59	0.010	70.4 ± 4.60	69.5 ± 5.24	0.623
Education, n (%)										
0-4	years	26 (56.5)	13 (46.4)	0.255	12 (52.2)	14 (60.9)	0.913	7 (50.0)	6 (42.9)	0.790
5-9		14 (30.4)	7 (25.0)		8 (34.8)	6 (26.1)		4 (28.6)	3 (21.4)	
> 9		6 (13.0)	8 (28.6)		3 (13.0)	3 (13.0)		3 (21.4)	5 (35.7)	
BMI, n (%)										
< 25	kg/m^2	14 (30.4)	6 (21.4)	0.698	6 (26.1)	8 (34.8)	0.710	3 (21.4)	3 (21.4)	0.476
25-29.9		22 (47.8)	15 (53.6)		11 (47.8)	11 (47.8)		9 (64.3)	6 (42.9)	
> 30		10 (21.7)	7 (25.0)		6 (26.1)	4 (17.4)		2 (14.3)	5 (35.7)	
Level of physical activity, n (%)										
Low		7 (15.2)	6 (21.4)	0.485	3 (13.0)	4 (17.4)	0.715	5 (35.7)	1 (7.1)	0.091
Moderate		14 (30.4)	11 (39.3)		6 (26.1)	8 (34.8)		6 (42.9)	5 (35.7)	
High		25 (54.3)	11 (39.3)		14 (60.9)	11 (47.8)		3 (21.4)	8 (57.1)	
Total water, mean ± SD	ml	2,118.8 ± 679.05	2,208.2 ± 848.49	0.619	1,884.3 ± 476.51	2,353.3 ± 775.34	0.018	1,999.4 ± 658.22	2,417.1 ± 983.91	0.198
Contribution of water from foods and beverages, mean ± SD										
Fruits	%	14.6 ± 9.95	13.0 ± 6.46	0.328	12.7 ± 10.51	16.5 ± 9.18	0.197	12.2 ± 7.05	13.2 ± 6.04	0.680
Dairy		14.7 ± 11.60	12.4 ± 10.06	0.403	14.2 ± 10.05	15.1 ± 13.20	0.801	10.6 ± 9.77	14.3 ± 10.35	0.329
Horticulture		16.6 ± 12.82	15.8 ± 14.87	0.828	16.1 ± 14.18	17.0 ± 11.60	0.814	17.8 ± 15.30	13.9 ± 14.73	0.500
Coffee, barley*		5.7 ± 6.97	4.8 ± 7.10	0.508	5.3 ± 5.63	6.1 ± 8.22	0.438	6.0 ± 7.80	3.6 ± 6.39	0.213
Other drinks*		2.4 ± 4.71	0.9 ± 4.92	0.70	1.4 ± 3.96	3.3 ± 5.27	0.097	1.9 ± 6.96	0.0 ± 0.00	0.150
Tea, infusions*		6.1 ± 9.40	9.1 ± 14.13	0.519	7.4 ± 9.83	4.9 ± 8.98	0.341	11.6 ± 17.71	6.5 ± 9.32	0.684
Water		22.4 ± 16.72	14.6 ± 19.00	0.070	23.0 ± 19.92	21.8 ± 13.20	0.813	9.3 ± 12.14	20.0 ± 23.25	0.143
Alcoholic beverages*		1.7 ± 4.04	10.5 ± 12.81	≤ 0.001	2.1 ± 3.90	1.3 ± 4.21	0.166	10.2 ± 7.13	10.8 ± 17.02	0.243
Other foods		15.9 ± 9.46	19.4 ± 10.23	0.130	17.7 ± 10.46	14.0 ± 8.14	0.184	20.5 ± 10.00	18.4 ± 10.74	0.597
Urinary parameters, mean ± SD										
Urine osmolality 24 h	mOsm/kg	402.7 ± 149.40	454.0 ± 158.46	0.166	512.9 ± 118.62	292.6 ± 78.76	< 0.001	573.3 ± 132,59	334.7 ± 62,65	< 0.001
Urinary volume 24 h	ml/day	1,832.0 ± 655.79	1,982.5 ± 654.24	0.341	1,364.8 ± 352.68	2,299.1 ± 546.77	< 0.001	1,457.9 ± 342.35	2,507.1 ± 423.02	< 0.001
Obligatory urine volume	ml/day	1013.2 ± 273.66	1251.0 ± 305.38	0.001	1,024.1 ± 270.72	1,002.4 ± 282.22	0.791	1,225.9 ± 257.21	1,276.0 ± 355.22	0.673
FWR 24 h	ml/day	818.7 ± 655.99	731.5 ± 582.35	0.565	340.7 ± 278.50	1,296.8 ± 569.94	< 0.001	231.9 ± 299.49	1,231.1 ± 277.60	< 0.001

** The distribution of these groups of food/beverages in the sample was different from the normal distribution, so in these cases we used the Mann Whitney test.*

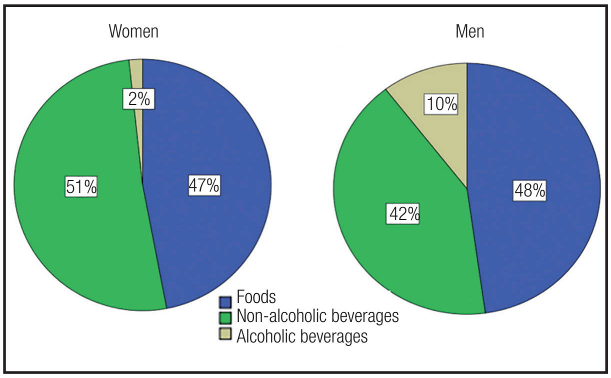

Figure 1.

Contribution of food, alcoholic and non-alcoholic beverages, by sex.

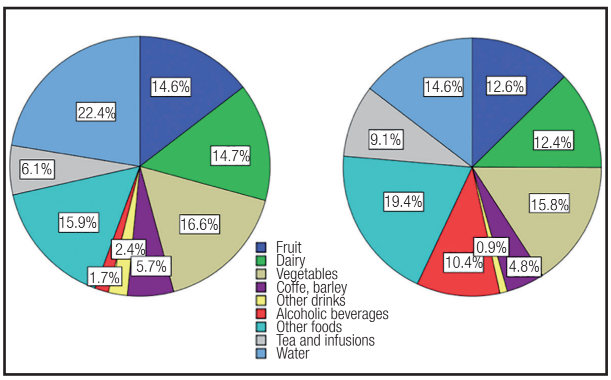

Figure 2.

Contribution of water intake by groups of food and beverages, by sex

DISCUSSION

In this study, total water intake was 2,208 ml in males and 2,118 ml in females. Approximately half of the participants did not reach the reference values of the European Food Safety Authority - EFSA, although the difference between mean and reference values was not statistically significant. When focusing on FWR values, most of the participants were classified as euhydrated. FWR appears to be a suitable method for the characterization of HS, given the inclusion of the maximum capacity of kidney concentration and a margin to ensure adequate intake of water in almost all healthy individuals (97%) of a population (27). A limitation of this study was the single recording period of 24 hours for food and urine collection, which may not represent an individual's normal behavior.

The total water intake was 2,153 ml/day on average; in the same range as the French (2,017 ml/day) (34) and German (2,334 ml/day) senior population (27), but less than the observed in the United States of America (2,650 ml/day) (35). However, it is important to consider the methodological differences in data collection across countries (36). It is also important to note that we have a convenience sample, avoiding the extrapolation of results for all non-institutionalized elderly. The study sample appears to be a special group with regard to water intake, possibly because it is a group of seniors who voluntarily attend an exercise program. That, by itself, can be understood as a group of people with specific characteristics regarding physical, cognitive and social factors. A study by Chidester et al. assumes that the non-institutionalized elderly are generally healthy and have easy access to a variety of drinks. The same study showed that institutionalized and dependent elderly are generally weaker and have a more limited access to beverages, hence at greater risk of dehydration (37).

The contribution of water from various groups of food and beverages did not differ between sexes, except for "alcoholic beverages". This contribution was significantly higher in men; almost half exceed alcoholic drinking recommendations, so, in part, the contribution of alcoholic beverages should revert to non-alcoholic drinks or water rich-foods, because, although the regular consumption of alcohol can reduce diuretic effects, a high consumption can be harmful to health (38). In women, the contribution of "non-alcoholic beverages" was significantly higher than in men. The same trend was observed in a study conducted in 2009 on a representative sample of the Portuguese adult population, in which women reported a higher intake of water, dairy products, tea and coffee, while men reported consuming a higher amount of alcohol (39).

"Water" and "foods with reduced water content" were the groups that contributed most to the total water intake in women and men, respectively. In this way, it is important to promote the consumption of non-alcoholic drinks and foods with a high water content, such as fruit and vegetables, to ensure adequate HS, in addition to other nutritional gains.

Even within the elderly, there appears to be differences in hydration parameters. Vivanti et al. reported that the elderly, aged 85 to 99, were six times more likely to be admitted to a hospital with dehydration in comparison to those aged 65-69 (40); this finding can be explained by the perception and response to stimulation of thirst (41). In addition, it was reported that from the age of 65, there is a decrease in water intake among the elderly (42). Although the importance of age in hydration studies is well known, we did not obtain data stratified by age, given the limited sample size. We found, however, that women classified above the median FWR were older than others.

CONCLUSIONS

Although most of the study participants were classified as euhydrated, the contribution of water-rich and nutritionally dense food, and non-alcoholic beverages, particularly in men, should be promoted.

DECLARATION OF INTEREST

P.P. was a member of the Scientific Board of the Institute of Hydration and Health between 2008 and 2015.

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