MAYO CLINIC

ORIGINAL ARTICLE

Association Between Dehydration and Falls

Irene Hamrick, MD; Derek Norton, MS; Jen Birstler, MS; Guanhua Chen, PhD; Laura Cruz; and Lawrence Hanrahan, PhD

Abstract

Objective: To determine whether there is an association between dehydration and falls in adults 65 years and older.

Patients and Methods: We used University of Wisconsin Health electronic health records from October 1, 2011 to September 30, 2015 to conduct a retrospective cohort study of Midwestern patients 65 years and older and examined the association between dehydration at baseline (defined as serum urea nitrogen to creatinine ratio > 20, sodium level > 145 mg/dL, urine specific gravity > 1.030, or serum osmolality > 295 mOsm/kg) and falls within 3 years after baseline while accounting for prescriptions of loop diuretic, antidepression, anticholinergic, antipsychotic, and benzodiazepine/hypnotic medications and demographic characteristics, using logistic regression.

Results: Of 30,634 patients, 37.9% (n=11,622) were dehydrated, 11.4% (n=3483) had a fall during follow-up, and 11.7% (n=3572) died during the follow-up period. We found a positive association of dehydration with falls alone (odds ratio [OR], 1.13; *P*=.002). For the outcome of falls or death, dehydration was positively associated (OR, 1.13; *P*=.001), along with loop diuretics (OR, 1.26; *P*<.001) and antipsychotic medications (OR, 1.52; *P*<.001).

Conclusion: More than one-third of older adults in this cohort were dehydrated, with a strong association between dehydration and falls. Understanding and addressing the risks associated with dehydration, including falls, has potential for improving quality of life for patients as they age.

 ■ Mayo Clin Proc Inn Qual Out 2020;4(3):259-265

From the University of Cincinnati College of Medicine, Cincinnati, OH (I.H.); and Departments of Biostatistics and Informatics (D.N., J.B., G.C.) and Family Medicine and Community Health (L.C., L.H.), University of Wisconsin, Madison.

Unintentional falls are a common occurrence among older adults, affecting approximately 30% of persons older than 65 years and 50% of those older than 80 years annually.[1] Falls are the leading cause of injury-related death in adults older than 65 years and the most common cause of nonfatal injuries and hospital admissions for trauma.[2] Each year 3 million nonfatal fall injuries among older adults are treated in emergency departments and more than 800,000 of these patients are hospitalized. In 2015, the direct medical costs of falls, were $50.0 billion. As the demographic characteristics of the US population shift to an increased number of elders, this problem is likely to get bigger and more expensive. Several factors contribute to falls: medications, infection, pain, muscle weakness, dehydration, etc.

Dehydration can lead to impaired brain perfusion, with subsequent dizziness and orthostasis.[3] Orthostatic hypotension has been associated with falls.[4] Decreased elasticity of aging tissues leads to decreased venous blood return when we arise and lowers diastolic blood pressure.[5] Add to this antihypertensive or diuretic medications or diseases that decrease compensatory mechanisms and falls can occur.[6] Although recent randomized controlled trials showed that antihypertensives do not increase fall risk, studies looking at the time of initiation or increase in antihypertensive medications have shown increased risk for falls, especially with diuretics, which deplete fluids.[6-10] Although there is a theoretical association between dehydration and falls, little is known about the prevalence of dehydration in older adults or the actual association between dehydration and falls.

We studied the associations between falls, dehydration, and medication use, as well as for falls or death.

PATIENTS AND METHODS

This retrospective cohort study was based on the University of Wisconsin Health Enterprise

Clarity Database in the Epic electronic health record (EHR) system and includes 600,000 patients seen each year in the Upper Midwest with approximately 1500 physicians and 16,500 staff at 6 hospitals and more than 80 outpatient sites. Data were cleaned of unreasonable covariate and laboratory values. Patient data were considered exempt by the University of Wisconsin Institutional Review Board policy.

On September 30, 2012 (baseline date), we identified 54,095 patients with 1 or more encounter within the previous year and 1 or more encounter within the 3 years after September 30, 2012 (October 1, 2012, through September 30, 2015). We chose to collect dehydration laboratory values before the time of falls reporting because many falls were reported after the occurrence and many patients did not have laboratory tests collected at the time and it provides a uniform time of dehydration assessment between those who did and did not fall. We chose a 1-year interval for laboratory result reporting because most individuals had some laboratory tests drawn within a year before baseline. Individuals were excluded if they did not have valid dehydration laboratory values or died before or on September 30, 2012, our baseline date (Figure 1). Other exclusion criteria were end-stage renal failure or liver disease (*International Classification of Diseases, Ninth Revision* [*ICD-9*] codes 585.6 and 570.0-573.3) at any point on or before baseline or during follow-up. In addition, patients were excluded if they reported a motor vehicle accident (codes E800-E879) or seizure (*ICD-9* codes 345.8, 345.9, and 780.39) if it occurred on or before the first fall during follow-up due to potential rhabdomyolysis affecting renal function. Laboratory values of the final cohort of 30,634 patients were positive for dehydration if any one

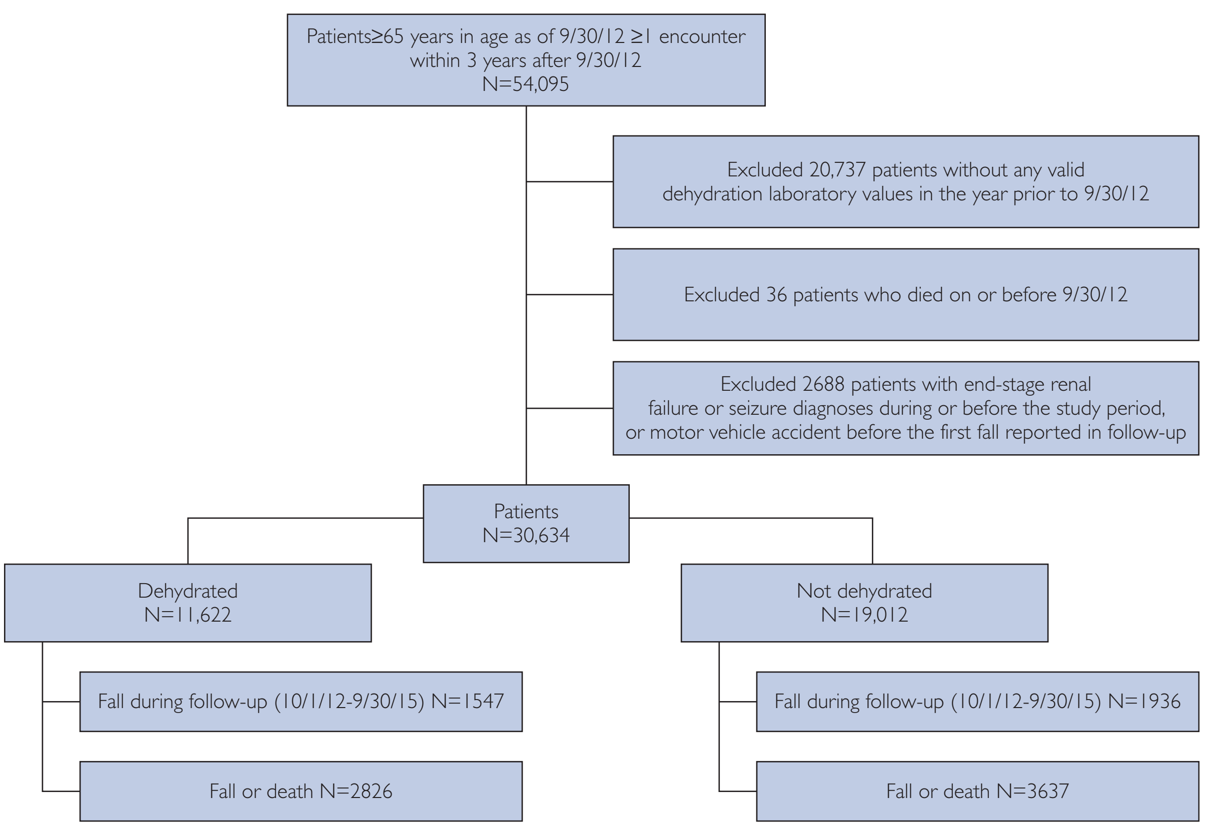

FIGURE 1. Flow diagram of selection process for cohort group.

Mayo Clin Proc Inn Qual Out ■ June 2020;4(3):259-265 ■ https://doi.org/10.1016/j.mayocpiqo.2020.01.003
www.mcpiqojournal.org

of the following were true in the year before baseline (October 1, 2011, through September 30, 2012): serum urea nitrogen to creatinine ratio > 20, sodium level > 145 mg/dL, urine specific gravity > 1.030, or serum osmolality > 295 mOsm/kg. If multiple values were available for a particular laboratory test, the value closest in time to baseline was used.

Outcome

The main outcome measure was diagnosis of a fall during the follow-up period. Falls diagnoses were identified by *ICD-9* codes E880 to E888. The secondary outcome was the composite of fall or death during the follow-up period as determined by a death date in the EHR during follow-up. Outcome variables were assessed in the follow-up period within the 3-year period after baseline. The follow-up period ended on September 30, 2015, shortly before the transition from *ICD-9* to *International Classification of Diseases, Tenth Revision* occurred.

Use of loop diuretics, anticholinergics, antidepressants, antipsychotics, and benzodiazepines/hypnotics was identified if such medications appeared in the drug list for any of the individual's records in the year before baseline. Other covariates included baseline age, sex, race/ethnicity (white non-Hispanic, black non-Hispanic, other non-Hispanic, and Hispanic), orthostatic hypotension (by most recent orthostatic blood pressure values in the year before baseline), congestive heart failure (*ICD-9* codes 398.91 and 428.0-428.9 in the diagnosis list or problem list in the year before baseline), and insurance. Baseline insurance was categorized as Hospice if paid toward hospice care regardless of insurance source, Standard for insurance paid toward any other goal regardless of insurance source, or None for those with no insurance. Thus, regardless of insurance type (ie, Medicare, Medicaid, or private), if they had insurance and it was being paid toward hospice care at baseline, insurance was categorized as Hospice; if any insurance was paid toward nonhospice care, insurance was categorized as Standard; those without insurance were categorized as None. Although insurance is typically categorized as, for example, Medicaid, Medicare, and private, the above categorization was chosen because it more directly reflects the goal of care and thus risk for the outcomes in our study. We also report percentages of individuals who have Medicaid or Medicare in the results and in the footnote of Table 1.

Statistical Methods

The association between dehydration and falls was examined using logistic regression, while including various medications of interest (loop diuretics, anticholinergics, antidepressants, antipsychotics, and benzodiazepines/hypnotics) known to affect falls risk as covariates in addition to the baseline subject covariates described. A similar model using the composite outcomes of falls or death was used to examine how the associations might be affected when considering death. Model diagnostics indicated no major concerns for overdispersion or poor fit. Unadjusted covariate distributions were compared between those who did and did not fall; continuous items were compared using Mann-Whitney tests; categorical items were compared using χ^2 or Fisher exact tests. Statistical significance was assessed at the α=.05 level for all tests. All analyses were performed using R, version 3.4.4 (R Foundation for Statistical Computing).[11]

RESULTS

Within the EHR, 54,095 individuals were identified with the appropriate baseline age and inclusion criteria for prebaseline and follow-up encounter occurrence. Of these, 20,737 patients were excluded due to no valid laboratory value for dehydration; 36 were excluded who died on or before September 30, 2012; and 2,688 were excluded with end-stage renal failure or seizure diagnoses during or before the study period or motor vehicle accident before the first reported fall in the follow-up period. The resulting sample for analysis contained a total of 30,634 individuals (Figure 1).

Patient Characteristics

Mean ± SD baseline age of the study population (N=30,634) was 74.37±7.58 years and 17,060 (55.7%) were women. The population was predominantly white non-Hispanic (94.6%; n=28,972) with 507 (1.7%) black non-Hispanic, 354 (1.2%) Hispanic, and 801 (2.6%) other non-Hispanic (Table 1). Most,

TABLE 1. Sample Characteristics[a,b]

	Whole Sample	Not Dehydrated	Dehydrated	*P*
N	30,634	19,012	11,622	
Dehydrated, no. (%)	11,622 (37.9)			
Fall(s) during follow-up, no. (%)	3483 (11.4)	1936 (10.2)	1547 (13.3)	<.001
Stroke(s) during follow-up, no. (%)	4470 (14.6)	2683 (14.1)	1787 (15.4)	.003
Died in follow-up, no. (%)	3572 (11.7)	2004 (10.5)	1568 (13.5)	<.001
Fall or death, no. (%)	6463 (21.1)	3637 (19.1)	2826 (24.3)	<.001
Stroke or death, no. (%)	7219 (23.6)	4226 (22.2)	2993 (25.8)	<.001
Congestive heart failure, no. (%)	1957 (6.4)	1002 (5.3)	955 (8.2)	<.001
Orthostatic blood pressure, no. (%)	240 (0.8)	133 (0.7)	107 (0.9)	.038
Depression meds, no. (%)	6525 (21.3)	3901 (20.5)	2624 (22.6)	<.001
Anticholinergic meds, no. (%)	10,172 (33.2)	6218 (32.7)	3954 (34.0)	.018
Psychotic meds, no. (%)	1605 (5.2)	981 (5.2)	624 (5.4)	.428
Hypnotic meds, no. (%)	11,337 (37.0)	7009 (36.9)	4328 (37.2)	.518
Loop meds; no. (%)	5377 (17.6)	2971 (15.6)	2406 (20.7)	<.001
Male sex, no. (%)	13,574 (44.3)	9736 (51.2)	3838 (33.0)	<.001
Age (y), mean ± SD	74.37±7.58	73.80±7.25	75.30±8.01	<.001
Race/ethnicity, no (%)				
White non-Hispanic	28.972 (94.6)	17.933 (94.3)	11.039 (95.0)	
Black non-Hispanic	507 (1.7)	385 (2.0)	122 (1.0)	<.001
Hispanic	354 (1.2)	200 (1.1)	154 (1.3)	
Other non-Hispanic	801 (2.6)	494 (2.6)	307 (2.6)	
Insurance category,[b] no. (%)				
Standard	25,750 (84.1)	16,213 (85.3)	9537 (82.1)	
Hospice	417 (1.4)	240 (1.3)	177 (1.5)	<.001
None	4467 (14.6)	2559 (13.5)	1908 (16.4)	

[a]Meds = medication.
[b]In the whole sample, 24,450 (79.8%) had Medicare and 86 (0.3%) had Medicaid. For those not dehydrated, 15,354 (80.8%) had Medicare and 43 (0.2%) had Medicaid. For those dehydrated, 9096 (78.3%) had Medicare and 43 (0.4%) had Medicaid.

24,450 (79.8%), had Medicare at baseline, and 25,750 (84.1%) had their insurance pay toward standard care (nonhospice care). Relatively few individuals, 86 (0.3%), were receiving Medicaid, and 417 (1.4%) had their insurance pay toward hospice care.

Falls and Dehydration

A total of 11,622 (37.9%) of the 30,634 patients studied were identified as dehydrated; 3483 (11.4%) were diagnosed with at least 1 fall during the follow-up period and 3572 (11.7%) died during follow-up, with 6463 (21.1%) having either a fall or death (Table 1). In the regression model for falls alone, dehydration was positively associated with falls (odds ratio [OR], 1.13; *P*=.002). For the same model structure with the outcome of falls or death, dehydration was also positively associated with the composite (OR, 1.13; *P*=.001; Table 2; Figure 2).

Falls and Medication Use

Of the 30,634 patients in the data set, at baseline, 6525 (21.3%) used antidepressants, 10,172 (33.2%) used anticholinergics, 1605 (5.2%) used antipsychotics, 11,337 (37.0%) used hypnotics, and 5377 (17.6%) used loop diuretics. The statistically significant medications associated with an increased risk for falls alone included antidepressants (OR, 1.58; *P*<.001), anticholinergics (OR, 1.24; *P*<.001), and hypnotics (OR, 1.31; *P*<.001). When the outcome is the composite of falls or death, all the medications were statistically significant and positively associated with falls or death: antidepressants, OR, 1.61 (*P*<.001); anticholinergics, OR, 1.28

Mayo Clin Proc Inn Qual Out ■ June 2020;4(3):259-265 ■ https://doi.org/10.1016/j.mayocpiqo.2020.01.003
www.mcpiqojournal.org

TABLE 2. Logistic Regression Results: Falls or Falls or Death Adjusted Models

	Falls			Falls or Death		
	P	OR Estimate	OR 95% CI	*P*	OR Estimate	OR 95% CI
Dehydrated	.002	1.13	1.05-1.22	.001	1.13	1.05-1.22
Depression meds	<.001	1.58	1.46-1.72	<.001	1.61	1.49-1.76
Anticholinergic meds	<.001	1.24	1.15-1.34	<.001	1.28	1.18-1.38
Antipsychotic meds	.862	1.01	0.87-1.18	<.001	1.52	1.32-1.76
Hypnotic meds	<.001	1.31	1.21-1.41	<.001	1.37	1.27-1.48
Loop meds	.286	1.06	0.96-1.17	<.001	1.26	1.15-1.39
Age (y)	<.001	1.07	1.07-1.08	<.001	1.07	1.07-1.08
Male	<.001	0.73	0.67-0.79	<.001	0.79	0.73-0.85
Congestive heart failure	.268	1.08	0.94-1.25	.002	1.25	1.09-1.44
Orthostatic blood pressure	.001	1.69	1.24-2.31	.005	1.63	1.16-2.28
Insurance: hospice	<.001	2.33	1.86-2.91	<.001	2.93	2.36-3.63
Insurance: none	.270	1.06	0.96-1.17	<.001	23.50	21.51-25.67

Meds = medications; OR = odds ratio.

(*P*<.001); hypnotics, OR, 1.37 (*P*<.001); antipsychotics, OR, 1.52 (*P*<.001); and loop diuretics, OR, 1.26 (*P*<.001).

DISCUSSION

This study showed strong evidence of an unadjusted association between falls and dehydration, with 13.3% (1547 of 11,622) falling for baseline dehydrated vs 10.2% (1936 of 19,012) if not dehydrated (*P*<.001). In logistic regression, this positive association remained after adjusting for medications and other subject characteristics associated with dehydration and/or falls risk. Sensitivity analyses assessing falls risk only for those who did not die in follow-up were also performed and resulted in no meaningful change in the association between dehydration and falls risk.

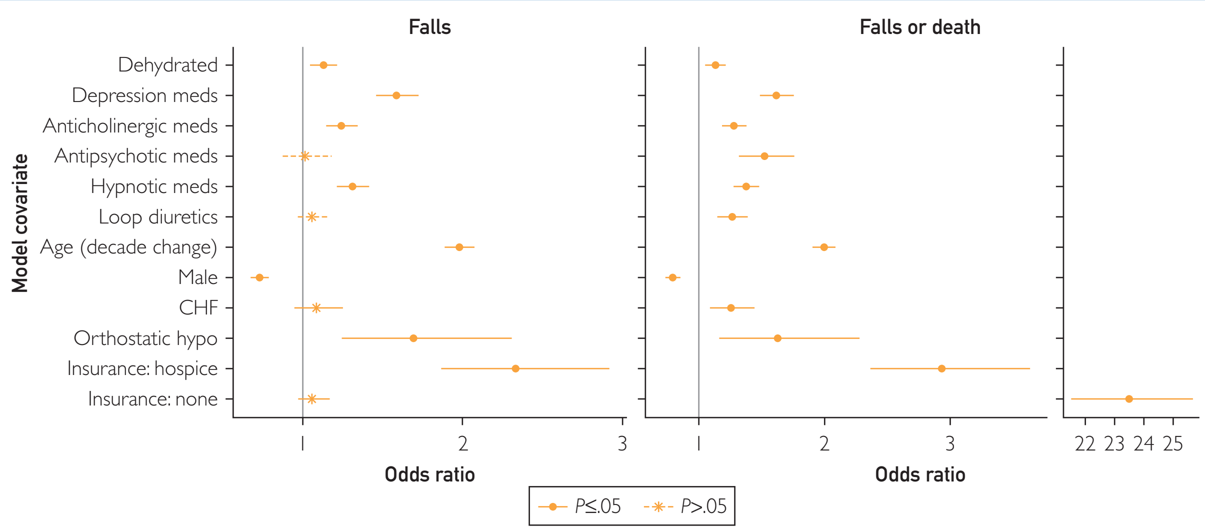

FIGURE 2. Falls and falls or death outcomes logistic regression results: estimated odds ratios with 95% CIs. CHF = congestive heart failure; hypo = hypotension; med = medication.

Interestingly, the covariate with the strongest association with the falls or death outcome was "no insurance" (OR, 23.50; 95% CI, 21.51-25.67). Those 65 years and older without insurance and ineligible for Medicare could be at greater risk for death due to less health care support, fewer resources, or other factors that make them ineligible for Medicare, such as immigration status.

We may have underestimated the prevalence of dehydration with stringent criteria. For example, older adults rarely concentrate their urine to greater than 1.030 because of atrophy of the long nephrons that are best at concentrating urine. As dehydration worsens, creatinine level increases, potentially narrowing the serum urea nitrogen to creatinine ratio to less than 20. Our study confirmed the association of death with antipsychotics, which led to the black box warning for this class of drugs.[12]

Older adults are at greater risk for dehydration because of several normal aging changes that occur throughout our lifespan. As we age, we feel less thirsty because of apoptosis of the hypothalamus, the thirst center location.[13,14] Apoptosis of neurons in the pituitary result in decreased antidiuretic hormone production. The aging kidney is less responsive to antidiuretic hormone and less able to concentrate urine with increasing age.[15,16] Our body water content also decreases from 70% at birth to 40% in older women and 45% in older men, leading to decreased fluid reserve.[17] In addition, many older adults limit their fluid intake in an attempt to prevent urinary and fecal incontinence.

Greater fluid losses in urine and less reserve increase adverse effects of dehydration. The Institute of Medicine recommends 2.7 L (91 ounces) of total water for women and 3.7 L (125 ounces daily) for men, with about 80% of it coming from beverages.[18] They also state that most healthy people adequately meet their daily hydration needs by letting thirst be their guide. As we age, apoptosis of the hypothalamus decreases thirst and the risk for dehydration increases.[14]

The ultimate goal is adequate hydration of our patients for optimal outcomes. As physicians we are responsible for identifying these aging changes and encouraging oral hydration, which improves blood osmolality better than intravenous fluids.[19] Many simple and cost-effective tools to help patients keep track of fluid intake exist: arranging 8 toothpicks near the sink and moving 1 toothpick with each glass of water to the other side of the sink, filling a half gallon pitcher of water that needs to be drunk by the end of the day; associating drinking with a common activity such as seeing a television commercial or answering an e-mail, or using a smartphone app that has an alarm reminder feature. The efficacy of these interventions to decrease patient-oriented outcomes needs to be tested in future studies.

Several limitations should be considered, including potential underreporting of falls by patients who may fear institutionalization. In addition, providers may not have listed falls because other diagnoses were perceived as more important or because the *ICD-9* code required the date of the fall, which may not be remembered by patients. The observational nature of these data prevents us from controlling for confounder through study design, necessitating control by statistical analysis. This study sample is a set of individuals self-selecting to interact with a single health care system. Therefore, risk estimates may not reflect what might be found in a statewide or nationwide representative sample. The laboratory values we used for dehydration are affected by medications, such as diuretics, and diseases, such as kidney failure. We excluded patients with a diagnosis of kidney failure, but there may have been an overlap of patients with kidney failure having been dehydrated that we excluded, and those with abnormal laboratory test results for dehydration having kidney failure.

Finally, we used a large observation window to capture exposures and outcomes. Using a snapshot of 1 year for laboratory identification of dehydration and the later (up to 3 years) identification of a fall could lead to missing or overidentifying associations. Obtaining laboratory results and medications in closer proximity to the time of the fall may be more accurate but may also miss many cases that did not have laboratory tests done upon presenting for a fall or did not fall. Being able to more regularly assess a cohort for dehydration would give a better estimate of association between dehydration and falls risk.

Mayo Clin Proc Inn Qual Out ■ June 2020;4(3):259-265 ■ https://doi.org/10.1016/j.mayocpiqo.2020.01.003
www.mcpiqojournal.org

CONCLUSION

There is strong observational evidence that supports an association between falls and dehydration and falls and the use of loop diuretics in the 65 year and older population. A future pragmatic trial of nursing homes that implement a hydration program, looking at patient-oriented outcomes of function, cognition, falls, and death, is warranted.

Abbreviations and Acronyms: **EHR** = electronic health record; ***ICD-9*** = *International Classification of Diseases, Ninth Revision*; **med** = medication; **OR** = odds ratio

Potential Competing Interests: The authors report no competing interests.

Correspondence: Address to Irene Hamrick, MD, 231 Albert Sabin Way, Medical Sciences Building, Rm 4111, PO Box 670504, Cincinnati, OH 45267 (hamricie@ucmail.uc.edu).

ORCID

Irene Hamrick: https://orcid.org/0000-0002-7207-2412

REFERENCES

1. Hausdorff JM, Rios DA, Edelberg HK. Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Arch Phys Med Rehabil*. 2001;82(8):1050-1056.
2. Hornbrook MC, Stevens VJ, Wingfield DJ, Hollis JF, Greenlick MR, Ory MG. Preventing falls among community-dwelling older persons: results from a randomized trial. *Gerontologist*. 1994;34(1):16-23.
3. Schroeder C, Bush VE, Norcliffe LJ, et al. Water drinking acutely improves orthostatic tolerance in healthy subjects. *Circulation*. 2002;106(22):2806-2811.
4. Gangavati A, Hajjar I, Quach L, et al. Hypertension, orthostatic hypotension, and the risk of falls in a community-dwelling elderly population: the maintenance of balance, independent living, intellect, and zest in the elderly of Boston study. *J Am Geriatr Soc*. 2011;59(3):383-389.
5. Timiras PS. *Physiological Basis of Aging and Geriatrics*. 2nd ed. Boca Raton FL: CRC Press; 1994:326.
6. Gribbin J, Hubbard R, Gladman J, Smith C, Lewis S. Risk of falls associated with antihypertensive medication: self-controlled case series. *Pharmacoepidemiol Drug Saf*. 2011;20(8):879-884.
7. Margolis KL, Palermo L, Vittinghoff E, et al. Intensive blood pressure control, falls, and fractures in patients with type 2 diabetes: the ACCORD trial. *J Gen Intern Med*. 2014;29(12):1599-1606.
8. SPRINT Research Group, Wright JT Jr, Williamson JD, Whelton PK, et al. A randomized trial of intensive versus standard blood-pressure control. *N Engl J Med*. 2015;373(22):2103-2116.
9. Lipsitz LA, Habtemariam D, Gagnon M, et al. Reexamining the effect of antihypertensive medications on falls in old age. *Hypertension*. 2015;66(1):183-189.
10. Sink KM, Evans GW, Shorr RI, et al. Syncope, hypotension, and falls in the treatment of hypertension: results from the randomized clinical Systolic Blood Pressure Intervention Trial. *J Am Geriatr Soc*. 2018;66(4):679-686.
11. R Core Team. The R Project for Statistical Computing. https://www.R-project.org 2017. Accessed June 10, 2018.
12. Schneider LS, Dagerman KS, Insel P. Risk of death with atypical antipsychotic drug treatment for dementia: meta-analysis of randomized placebo-controlled trials. *JAMA*. 2005;294(15):1934-1943.
13. Phillips PA, Rolls BJ, Ledingham JG, et al. Reduced thirst after water deprivation in healthy elderly men. *N Engl J Med*. 1984;311(12):753-759.
14. McKinley MJ, Johnson AK. The physiological regulation of thirst and fluid intake. *News Physiol Sci*. 2004;19:1-6.
15. Miller JH, Shock NW. Age differences in the renal tubular response to antidiuretic hormone. *J Gerontol*. 1953;8(4):446-450.
16. Rowe JW, Shock NW, DeFronzo RA. The influence of age on the renal response to water deprivation in man. *Nephron*. 1976;17(4):270-278.
17. Mentes JC. A typology of oral hydration problems exhibited by frail nursing home residents. *J Gerontol Nurs*. 2006;32(1):13-19. quiz 20-21.
18. Institute of Medicine (US); Panel on Macronutrients, Institute of Medicine (US); Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: National Academies Press; 2005;xxv:1331.
19. Bhalla A, Sankaralingam S, Dundas R, Swaminathan R, Wolfe CD, Rudd AG. Influence of raised plasma osmolality on clinical outcome after acute stroke. *Stroke*. 2000;31(9):2043-2048.