Elevated Serum Osmolality and Total Water Deficit Indicate Impaired Hydration Status in Residents of Long-Term Care Facilities Regardless of Low or High Body Mass Index

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ABSTRACT

Background Dehydration is typically associated with underweight and malnutrition in long-term care (LTC) settings. Evidence is lacking regarding the influence of the rising prevalence of overweight and obesity on risk factors, prevalence, and presentation of dehydration.

Objective The aim of this study was to objectively assess hydration status and the adequacy of total water intake, and determine relationships between hydration status, total water intake, and body mass index (BMI) in LTC residents.

Design A cross-sectional analysis of baseline data was performed.

Participants and setting Baseline data from 247 subjects recruited from eight community-based LTC facilities participating in two randomized trials comparing nutrient and cost-efficacy of between-meal snacks vs oral nutrition supplements (ONS).

Main outcomes Hydration status was assessed by serum osmolality concentration and total water intakes were quantified by weighed food, beverage, water, and ONS intake.

Statistical analyses Simple and multiple linear regression methods were applied.

Results Forty-nine (38.3%) subjects were dehydrated (>300 mOsm/kg) and another 39 (30.5%) had impending dehydration (295 to 300 mOsm/kg). The variance in serum osmolality was significantly accounted for by blood urea nitrogen level, mental status score, and having diabetes (R^2=0.46; P<0.001). Total water intake averaged 1,147.2±433.1 mL/day. Thus, 96% to 100% of subjects did not meet estimated requirements, with a deficit range of 700 to 1,800 mL/day. The variance in total water intake was significantly accounted for by type of liquid beverages (thin vs thick), type of ONS, total energy intake, total activities of daily living dependence, sex, and BMI (R^2=0.56; P<0.001).

Conclusions Dehydration and inadequate total water intake is prevalent in LTC residents across all BMI categories. Type of liquid beverages, type of ONS, and type of between-meal snacks are factors that could be targeted for nutrition interventions designed to prevent or reverse dehydration.
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IT HAS LONG BEEN RECOGNIZED THAT DEHYDRATION IS a common and costly disorder among older adults regardless of whether they are living in home, community, or long-term care (LTC) settings.[1] Dehydration occurs when total body water (and electrolytes) is inadequate to maintain fluid balance and normal physiologic functions.[2]

To take the Continuing Professional Education (CPE) quiz for this article, log in to www.eatrightPRO.org, go to the My Account section of the My Academy Toolbar, click the "Access Quiz" link, click "Journal Article Quiz" on the next page, and then click the "Additional Journal CPE quizzes" button to view a list of available quizzes. CPE quizzes are available for 1 year after the issue date in which the articles are published.

Common factors promoting inadequate repletion of total body water include bleeding; vomiting; diarrhea; fever; excessive sweating; having draining wounds or burns; polyuria; and, most often, inadequate fluid intake. The many consequences of dehydration include constipation, hypotension, pneumonia, seizures, urinary tract infections, bladder cancer, kidney failure, heart disease, confusion, delirium, and development of pressure ulcers.[3-5] Notably, more than 100,000 adults aged ≥65 years were admitted to US hospitals with a primary diagnosis of dehydration in 2011.[6] With an average length of stay of 3.6 days, hospital costs from dehydration amount to ~$6 billion per year.[6] Consequently, dehydration has continued to be a key quality of care indicator for the Agency for Healthcare Research and Quality's prevention of hospitalization goals since 2001.[7] Of greatest concern is that dehydration increases mortality risk when left untreated.[8,9]

Historically, dehydration has been most often recognized and evaluated in both clinical practice and research in the context of LTC residents being underweight or malnourished.[8,10-12] However, the influence of the rising prevalence of overweight and obesity among LTC residents, now estimated at ≥25% of the LTC population,[13] has not been fully considered or well investigated. Because overweight/obese residents are likely to have more comorbidities,[14] it is important to better understand the signs, symptoms, and effects of impaired hydration status in LTC residents in all body mass categories. Regardless of body weight, several biological, physiological, and psychological factors contribute to increased risk for dehydration among older adults. One factor is the relative decrease in the proportion of lean soft tissue to fat mass that occurs with aging (ie, aging-related sarcopenia), which reduces total body water content.[15] Secondly, aging-related decline in kidney function makes it more difficult to concentrate urine and conserve body water.[16] Further complicating hydration status, reduced thirst sensation from impaired sensitivity to baroreceptor stimulation decreases fluid consumption.[17-19] Moreover, residents with cognitive impairment may be unaware of their needs and, thus, forget to drink or request beverages. In addition, residents who are incontinent may intentionally restrict their fluid intake due to fear of accidents.[20,21] Others with physical disabilities may not have the manual dexterity or strength to hold or lift a cup. Moreover, low staff to resident ratios in LTC facilities limit the assistance provided with food and beverage consumption.[4] Finally, use of anorexigenic medications may contribute to inadequate food and beverage intake and medications with high osmolarity may increase body water losses.

Determining how much total water older adults require to prevent becoming dehydrated is difficult because no standardized criterion of hydration status or tool to assess hydration exists for this population. Although not validated against objective methods such as water balance or turnover studies,[22,23] various formulas are used in clinical practice to estimate total water needs. Two commonly used formulas are derived from body weight. One, the Linear formula, is based on the amount of water needed per kilogram of body weight to compensate for normal daily water losses plus losses from vomiting, diarrhea, fever, and/or hemorrhage.[24] The other, the Adjusted formula, was established to determine water needs for adults receiving enteral nutrition support (tube feeding) and provides at least 1,500 mL/day for those weighing more than 20 kg.[25,26] It has not been determined whether these formulas are appropriate for individuals who have higher body mass (ie, those who are overweight or obese). More recently, the Institute of Medicine (IOM) Food and Nutrition Board determined that total water intake of 2,700 mL/day for women and 3,700 mL/day for men is adequate to meet the needs of the general healthy adult population.[22]

Studies comparing total water intakes from foods and beverages to determine adequacy of intakes based on estimates from the Linear and Adjusted formulas indicate that 46% to 90% of older LTC residents do not meet their daily total water requirements.[27-29] However, in most prior investigations the primary indicator of hydration status, directly measured plasma or serum osmolality, has not been included. In addition, total water intakes have been determined subjectively by visual estimation rather than using objective methods such as direct weighing of foods and beverages consumed. The primary aim of this study was to objectively assess hydration status and the adequacy of total water intakes among LTC residents who encompass the range of body mass index (BMI) categories. A secondary aim was to identify relationships between hydration status, total water intakes, and BMI. To better inform these aims, fluid consumption patterns in these LTC residents were also assessed.

METHODS

Subject Population and Recruitment

For the present study, baseline data were analyzed from 247 subjects who were recruited from eight community-based LTC facilities in the greater metropolitan Nashville, TN, area. Subjects were enrolled in two randomized controlled trials, one to compare the cost-effectiveness of between-meal snacks vs oral nutritional supplements (ONS) and the other to compare the efficacy on caloric intake and weight status over a 6-month intervention period. Both trials were approved by the Vanderbilt Institutional Review Board and registered at ClinicalTrials.gov (NCT02567513 and NCT02567526). The eight LTC facilities housed a total of 1,152 residents (88% occupancy). In these facilities, staff-to-resident ratios ranged from 6.3 to 10.8 residents per nurse aide during daytime (7 AM to 3 PM) and 7.8 to 14.6 at night (3 PM 11 PM), with a total staffing (nurse aides plus licensed nurses) ratio of 2.9 to 5.0 hours/day per resident. Of the 1,152 residents (Figure 1), 428 met the main study inclusion criteria of being long-stay (not admitted for short-term rehabilitation), not being provided with enteral or parenteral nutrition, not receiving hospice care, and having a written order for daily caloric supplementation (between-meal snacks or ONS). Signed informed consent was obtained for 276 residents. If the facility nursing staff had documented in the medical record a resident's inability to make decisions or a resident was unable to respond readily and clearly to a series of structured questions witnessed by an independent observer, then the resident's responsible party provided consent. This was the case for 64.5% of consents obtained, with no difference in the proportion of consents from a resident's responsible party by LTC site (P=0.69).

Physical and Psychological Assessments

Upon consent, demographic (age, sex, and race) and clinical data (medical diagnoses, medications, and diet orders) were obtained from subjects' medical records. Functional dependence scores were acquired from the subject's most recent Minimum Data Set (MDS) assessment, which had been performed by nursing staff using the MDS-derived activities of daily living scale (MDS-ADLs) wherein scores range from 0 (independent in each of seven activities) to 28 (fully dependent in all activities).[30] Cognitive status was assessed using the Mini Mental State Exam with scores ranging from zero (severely impaired) to 30 (cognitively intact).[31] Trained research personnel measured body weight and knee height using standardized protocols[32] and calculated BMI as weight

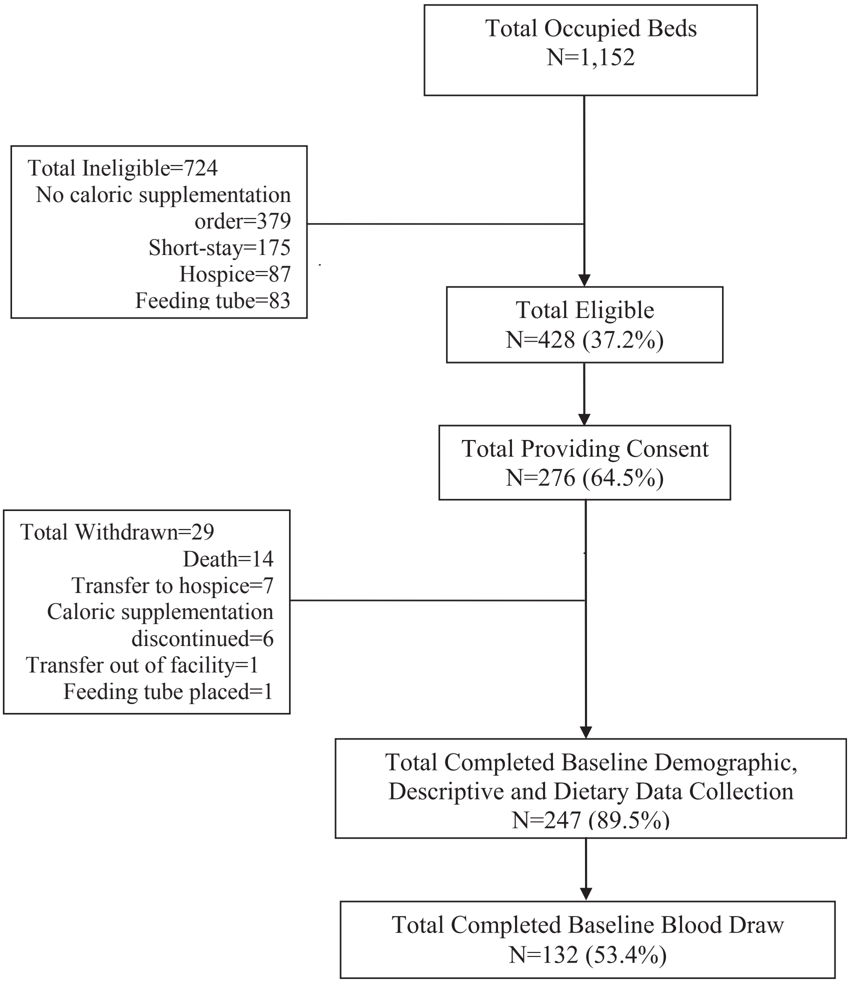

Figure 1. Flow diagram depicting study recruitment and retention of older adults from eight long-term care facilities participating in a study to determine relationships between hydration status, total water intake, and body mass index.

(in kilograms)/height (in meters^2).[33] To provide insight whether the quality of the foodservice might be a factor in total energy or water intake, subjects were interviewed regarding their satisfaction with the foods served using a validated 5-item food satisfaction questionnaire.[34]

Hydration Status and Total Water Intakes

Blood samples, collected by research nurses, were obtained upon consent (~10 days before baseline food and beverage data collection), stored on ice, and transported later on the day of collection to the Vanderbilt University Clinical Pathology Lab for analysis of blood urea nitrogen (BUN), serum creatinine, and serum osmolality concentrations determined by freezing point depression with results read directly from the instruments (Advanced 1M Micro-Osmometer Model 3MO, Advanced Instruments, Inc). The analytical coefficient of variation for osmolality measurements was 0.78%.

Weighed intakes of foods, beverages, cups of water, and ONS were acquired by trained research personnel at all meal and snack times within two nonconsecutive 24-hour weekday periods during the 10-day baseline data collection period. Before being served, items were weighed (±0.1 g) using a calibrated, digital, portable scale (Ohaus FD Series Food Portioning Scale). Research personnel then observed every meal and snack time for a period of 90 minutes each (averaging a total of 540 minutes per 24-hour period) to ensure that all foods, beverages, cups of water, and ONS consumed were accounted for. After each consumption episode, research personnel collected foodservice trays and all other individual items directly from the residents' rooms and brought them to a private room for reweighing of all items. Weighed data were entered into Nutrition Data System for Research software (version 2012, University of Minnesota Nutrition Coordinating Center) at the Vanderbilt Nutrition and Diet Assessment Core Lab and analyzed for energy, nutrient, and total water intake (foods, beverages, water, and ONS).

Data Analysis

BMI was categorized based on World Health Organization classification[33] for some analyses where it simplified and informed the interpretation of the results. To determine whether serum osmolality concentration indicated dehydration, a cut-point of >300 mOsm/kg was used to reflect being

Table 4. Baseline demographic, dietary, functionality and comorbidity characteristics of 247 subjects recruited from eight long-term care facilities to participate in a study to determine relationships between hydration status, total water intake, and body mass index (BMI)

Characteristic	Result
	←mean±standard deviation→
Age (y)	82.9±11.3
Length of stay (mo)	39.4±42.9
Height (cm)	158.6±8.9
Weight (kg)	61.5±13.4
BMI	24.5±4.7
MMSE[a] (score)	12.0±8.1
MDS-ADL[b] (score)	18.7±5.7
	←n (%)→
Women	194 (78.5)
Men	53 (21.5)
Non-Hispanic white	169 (68.4)
Non-Hispanic black	78 (31.6)
Medical comorbidity	
Dementia	188 (76.1)
Depression	166 (67.2)
Dysphagia	112 (45.3)
Type 2 diabetes	71 (28.7)
Chronic renal failure	54 (21.9)
Chronic obstructive pulmonary disease	45 (18.2)
Cancer	18 (7.3)
Diet prescription	
Oral nutritional supplements	180 (72.8)
Modified diet[c]	173 (70.0)
Mechanical soft	95 (38.5)
Sodium restricted	46 (18.6)
No concentrated sweets	44 (17.8)
Pureed	44 (17.8)
Thickened liquids	24 (9.7)
Double portions of meat and vegetables	17 (6.9)

[a]MMSE=Mini Mental State Examination; scored as 0 to 30, with lower score indicating greater cognitive impairment.
[b]MDS-ADL=Minimum Data Set Activities of Daily Living scored as 0 to 28, with higher score indicating greater dependence.
[c]Subjects could have more than one type of dietary modification.

currently dehydrated and the range of 295 to 300 mOsm/kg as indicative of impending dehydration.[2] To determine the adequacy of total water intake, the 2-day average for each subject was compared with his/her estimated requirement using the Linear formula (30 mL/kg actual body weight with a minimum of 1,500 mL/day),[24] the Adjusted formula (sum of 100 mL/kg for first 10 kg body weight+50 mL/kg for second 10 kg body weight+15 mL/kg for remaining kilograms of body weight),[26] and the IOM formula (2,700 mL/day for women and 3,700 mL/day for men).[22] Contents of foods, beverages, snacks, and ONS consumed throughout the data collection periods were used to identify patterns of fluid intake.

Statistical analyses were performed using R software, version 3.1.2, and associated extension packages (2014, R Foundation for Statistical Computing). The Mann-Whitney *U* test was used to compare variables by sex and the Kruskal-Wallis test was used to compare by BMI category. Univariate relationships were first assessed using Spearman rho correlation coefficients (Table 1, available online at www.andjrnl.org) and then confirmed using linear regression (R function "lm"). Associations between continuous variables were modeled using a smooth nonlinear function (R function "bs" from the splines package). Analysis of variance was used to assess the significance of marginal associations and the coefficient of determination (adjusted R^2) was used to summarize the strength of an association. Multiple linear regressions were then performed using variables that showed significance in the univariate analyses to determine which factors retained significance in accounting for the variance in the outcomes of serum osmolality concentration and total water intake when the other influential variables were included in the models. Data are presented as mean± standard deviation unless otherwise noted. P values <0.05 were considered significant in all statistical tests performed, except P=0.10 was used for initial multivariate modeling (Tables 2 and 3, available online at www.andjrnl.org).

RESULTS

Subject Characteristics

Of the 276 subjects who consented to participate, 247 (89.5%) completed baseline data collection. These 247 subjects had been LTC residents for an average of 39.4±42.9 months. No significant differences were observed among the eight LTC sites for resident length of stay (P=0.87), age (P=0.39), BMI (P=0.86), or functionality (MDS-ADL score) (P=0.12). There was also no difference by LTC site in the proportion of residents who were women (P=0.17).

In the group of 247 residents, 79% were women, 68% were non-Hispanic white, and 32% were non-Hispanic black (Table 4). On average, female subjects were older than male subjects (84.9±10.1 vs 75.6±12.6 years; P<0.001). The average BMI was 24.5±4.7, with only 7% of subjects classified as underweight (BMI <18.5), 51.3% were normal weight (BMI 18.5 to 24.9), 30.3% were overweight (BMI 25 to 29.9), and 11.4% were obese (BMI ≥30).

With an average Mini Mental State Exam score of 12.0±8.1, a majority (76.1%) of subjects had dementia and two-thirds (67.2%) had depression. Most (81%) subjects were rated by LTC staff as dependent in at least one ADL, with an average MDS-ADL score of 18.7±5.7 indicating a moderate degree of functional dependence. However, 134 (54.3%) were rated as being in need of assistance with eating and drinking. The positive association between eat/drink dependence and BMI trended toward being significant (r=0.23; P=0.06).

Table 5. Baseline serum concentrations of biomarkers of hydration status by body mass index (BMI) category in long-term care residents recruited from eight facilities to participate in a study to determine relationships between hydration status, total water intake, and body mass index[a]

BMI category[b]	n	Serum osmolality (mOsm/kg)		BUN[c] (mg/dL)	BUN:Cr[d] (mg/dL)
		mean±SD[e]	*n (%) ≥295*[f]	*mean±SD*	
Underweight	10	301.4±7.1	9 (90.0)	18.7±6.9	21.7±9.6
Normal weight	65	300.0±8.0	47 (72.3)	22.1±8.7	22.4±7.4
Overweight	41	298.0±10.1	28 (68.3)	21.7±14.8	20.5±7.8
Obese	12	293.8±7.8	4 (33.3)	16.8±8.1	20.7±8.0

[a]Serum biomarkers and BMI available for 128 of 247 enrolled subjects due to limitations of no blood draw (n=115) or amputation (n=4).
[b]Underweight=BMI <18.5, normal=BMI 18.5-24.9, overweight=BMI 25-29.9, and obese=BMI 30-39.9.
[c]BUN=blood urea nitrogen.
[d]BUN:Cr=blood urea nitrogen to creatinine ratio.
[e]SD=standard deviation.
[f]Cut-point of ≥295 indicates current (≥300 mOsm/kg) or impending (295 to 300 mOsm/kg) dehydration.

Hydration Status

Blood levels for serum osmolality, serum creatinine, and BUN were available for subjects from five of the eight sites due to the research agreements with the sites. In these 132 subjects (53.4% of total enrolled subjects), serum osmolality concentration averaged 298.9±8.8 mOsm/kg. Using the cut-point of >300 mOsm/kg, 49 (38.3%) subjects were dehydrated and an additional 39 (30.5%) had impending dehydration with levels between 295 and 300 mOsm/kg. Although subjects with lower BMI had higher serum osmolality (R^2=0.05; P=0.01), one-third of those who were obese had levels ≥295 mOsm/kg (Table 5). The average BUN level was 21.3±11.0 mg/dL and average BUN:creatinine was 21.4±7.6. Almost one-third (31.6%) of subjects had BUN:creatinine ≥25 mg/dL. Both BUN and BUN:creatinine were positively associated with serum osmolality (R^2=0.39; P=0.001 and R^2=0.09; P=0.006, respectively). Multiple linear regression showed that the variables most significantly accounting for the variance in serum osmolality were BUN, mental status score, and having diabetes (Table 3, available online at www.andjrnl.org) (R^2=0.46; P<0.001).

Dietary Intake

Results from the food satisfaction survey, completed by 98% of subjects, showed that 64% liked the food items served, 62% reported food item variety was adequate, 61% reported food items looked appealing, 62% reported food items were served at an appropriate temperature, and 42% had reported no food complaints during the baseline period. Seventy percent of subjects were consuming a modified diet and 180 (72.8%) had a written order for liquid ONS (Table 4), including 53 subjects in the overweight and obese BMI categories. Of the subjects receiving ONS, 158 (87.8%) were prescribed high-calorie formulas (>1.5 kcal/mL).

Table 6. Baseline energy intake, total water intake, and estimated total water requirements by body mass index (BMI) in 247 subjects recruited from eight long-term care facilities participating in a study to determine relationships between hydration status, total water intake, and body mass index

BMI category[a]	n	Energy Intake (kcal/d)	Total Water Intake (mL/d)	Estimated Total Water Requirement: Linear[b]	Adjusted[c]	IOM[d]
		←mean±standard deviation→				
Underweight	18	1,514.6±711.3	942.5±383.7	1,533.3±94.9	1,856.8±111.1	2,950.0±447.2
Normal weight	120	1,590.1±468.1	1,113.5±416.6	1,680.5±203.4	2,028.3±114.5	2,913.7±411.7
Overweight	70	1,528.5±502.8	1,196.6±411.3	2,030.0±257.8	2,215.0±128.9	2,917.4±415.5
Obese	30	1,552.4±563.8	1,290.4±537.9	2,511.1±363.5	2,455.5±181.7	2,892.3±401.9

[a]Underweight=BMI <18.5, normal=BMI 18.5-24.9, overweight=BMI 25-29.9, and obese=BMI 30-39.9.
[b]Linear formula: 30 ml/kg body weight (minimum of 1,500 mL/day).
[c]Adjusted formula: sum of 100 mL water/kg for the first 10 kg actual body weight, 50 mL water/kg for the next 10 kg, and 15 mL water/kg for the remaining kilograms of weight.
[d]IOM=Institute of Medicine formula: adequate intake=2,700 mL/day for women and 3,700 mL/day for men.

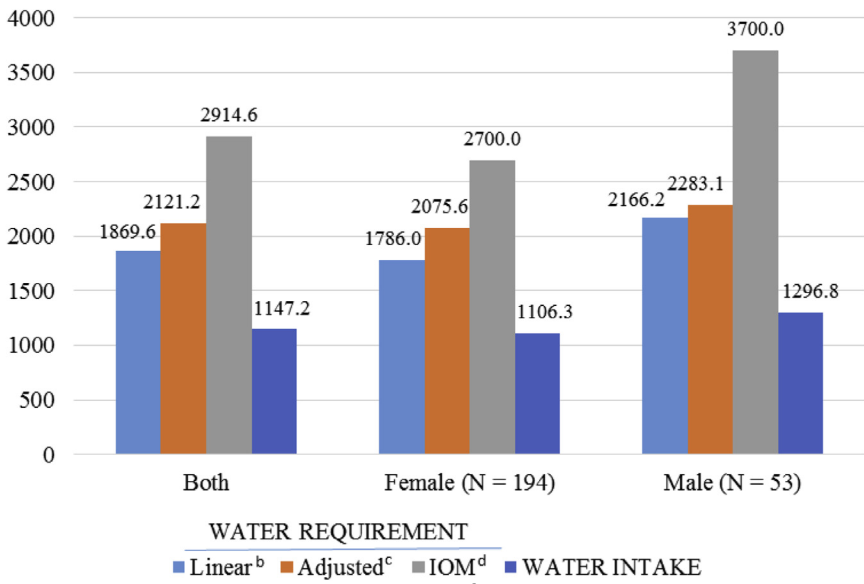

Figure 2. Estimated total water requirement and total water intake[a] in 247 long-term care residents from eight facilities participating in a study to determine relationships between hydration status, total water intake, and body mass index. [a]Average total water intake from all foods, beverages, cups of water, and oral nutritional supplements consumed within 24-hour study periods. [b]Linear formula: 30 mL/kg body weight (minimum of 1,500 mL/day). [c]Adjusted formula: Sum of 100 mL water/kg for the first 10 kg actual body weight, 50 mL water/kg for the next 10 kg, and 15 mL water/kg for the remaining kilograms of weight. [d]IOM=Institute of Medicine. IOM formula: Adequate Intake (2,700 mL/day for women, 3,700 mL/day for men).

Overall, average energy intake was 1,555.4±514.2 kcal/day with 36.4% of calories from fat, 49.0% from carbohydrate, and 14.6% from protein. As expected, women had significantly lower average energy intake than men (1,501.2±503.4 vs 1,753.9±509.1 kcal/day; P=0.001). No significant difference was detected in energy intake by age (F=5.15; P=0.34), mental status (F=2.09; P=0.51), or BMI category (F=1.14; P=0.65).

Total Water Intake

No difference in total water intake was observed in residents categorized by LTC site (P=0.25) or average length of stay (P=0.87). Overall, average total water intake was 1,147.2±433.1 mL/day (1,106.3±401.3 mL/day for women vs 1,296.8±510.6 mL/day for men; P=0.01). Total water intake was positively associated with caloric intake (R^2=0.37; P<0.001). Total water intake was also associated with beverage consistency (R^2=0.11; P<0.001), with greater total water intake in those consuming thin (vs thickened) liquids (90.3% subjects). Interestingly, no difference in total water intake was detected based on the number (one, two, or three) of between-meal snacks served daily (R^2=0.01; P=0.40). In contrast, subjects who were prescribed ONS had lower total water intakes than those without ONS orders (1,081.9±410.6 mL/day vs 1,322.5±446.2 mL/day; P=0.001).

Total water intake increased with BMI, with significantly greater total water intake in subjects in the overweight and obese categories compared with those in the underweight category (P values=0.01) (Table 6). Nevertheless, higher requirement was associated with greater deficit, regardless of estimation formula used (eg, Linear formula [R^2=0.28; P<0.01]). Hence, average total water deficit was greatest in subjects with the highest BMI. Thus, almost all (96%) subjects had total water intake significantly less than their estimated requirement based on the Linear equation and all (100%) subjects had total water intake less than required based on the Adjusted and IOM formulas (all P values <0.01) (Figure 2). Across the three formulas, the deficit in meeting estimated total water requirement ranged from 700 to 1,800 mL/day. In subjects prescribed ONS, the total water deficit tended to be greater with high calorie vs standard ONS (P=0.09). Multiple linear regression showed that the variables most significantly accounting for the variance in total water intake were type of liquid beverages (thin vs thick), type of ONS, total energy intake, total ADL dependence, sex, and BMI (Table 2, available online at www.andjrnl.org) (R^2=0.56; P<0.001).

Patterns of Total Water Intake

The percentage of total water intake from breakfast (380 g/day), lunch (351 g/day), and dinner (341 g/day) meals was distributed evenly (32%, 30%, and 29%, respectively) and 9% of water intake came from snacks (104 g/day). Most (79%) water intake came from consuming beverages and drinking water, not solid foods. In assessing the sources of water intake by beverage type, milk-based beverages provided 22% of water intake; coffee, tea, soda, and cups of water provided 21%; fruit and fruit-flavored juice provided ~17%; and soups provided ~12% of water intake. Additional water intake from solid foods came mostly from consuming fruits and vegetables (7%) as well as dairy-based food items and eggs (7%).

DISCUSSION

In the present study, objective methods were used to measure body mass, serum biomarkers, and total water intake to enable assessment of hydration status and adequacy of total water intakes among LTC residents across the range of BMI categories. Serum osmolality concentration, the main physiologic signal regulating water balance[35] and reference standard for diagnosing dehydration in older adults,[2] indicated that the majority (68.8%) of subjects were either currently dehydrated or had impending dehydration. Hence, despite being a quality of care indicator, the prevalence of dehydration remains consistent with that previously reported from National Health and Nutrition Examination Survey data in community-residing older adults.[36] Although it may be expected that residents of higher body weight would have less total water deficit as an effect of greater food and/or beverage intake, an important finding was that the proportion of subjects showing current or impending dehydration did not differ by BMI. Although the proportion of subjects who were obese at baseline (BMI $\geq$30) with current or impending dehydration was less than other BMI categories, when combined with those who were overweight (BMI 25.0 to 29.9), only 39.6% of overweight/obese subjects had a serum osmolality concentration that would be considered in the range of normal ($<$295 mOsm/kg). Thus, the problem of dehydration appears to be affecting overweight and obese LTC residents at least as much as those who are underweight.

Although small changes in blood osmolality should stimulate homeostatic mechanisms that trigger maintaining water balance by increasing intake, impaired responsiveness to these triggers (ie, release of antidiuretic hormone and increased thirst) is associated with aging. Therefore, another key finding was that almost all subjects had inadequate total water intake. This finding was present regardless of which estimation formula was used to determine the adequacy of total water intake, even when based on body weight. Overall, total water deficit ranged from 700 to 1,800 mL/day. This finding contrasts with prior reports where the prevalence of inadequate intake in LTC was substantially lower, occurring in ~50% of residents.[27-29] It is likely that the visual observation method used in these other studies overestimated total water intake, especially in subjects with low consumption.[37] It is notable that although subjects who were overweight or obese had higher total water intakes, they also had greater total water deficits—meaning they were less likely to be meeting their estimated minimum requirement for normal physiologic losses.

Because water is an essential nutrient, with only a small amount produced by metabolic oxidation of macronutrients, intake is highly dependent on the amount and type of food and beverage intake. Thus, a contributing factor to having inadequate total water intake could be dislike or dissatisfaction with the food being served. Yet, in the present study two-thirds of subjects reported no problems with the appeal, variety, and temperature of food items served. Another plausible factor would be having an unmet need for assistance with eating and drinking. Although the present data do not inform this question, prior work from this group[38] shows LTC staff spend fewer than 10 minutes per resident providing assistance during mealtimes. Notably, most (81%) subjects in the present study were rated as being dependent in at least one activity of daily living, with MDS-ADL scores suggesting at least a moderate level of physical function decline. Moreover, scores for eating/drinking dependence suggest that more than half of subjects were in need of direct assistance. This decline in functional ability to consume adequately may be especially problematic for the oldest LTC residents. In the present data, age 70 years was a noticeable cut-point where total water intakes decreased. Consistent with this finding, National Health and Nutrition Examination Survey data show a higher serum osmolality level from age 70 years onward.[22]

It is interesting that there was no difference in total water intake between subjects receiving between-meal snacks vs no snacks. Although multiple snacks may be provided in an effort to increase energy and nutrient intake when there is weight loss or inadequate food intake, it is possible that snacks are not being consumed due to lack of assistance or that they are being served unaccompanied by beverages or cups of water. Most surprising is that subjects who had a prescription for an ONS had lower total water intakes than those without ONS orders. Previous studies show that whereas ONS are a common treatment for LTC residents with inadequate caloric intake, an adverse consequence may be energy compensation by reducing food intake at mealtimes within the 24-hour period.[39]

In addition to greater dehydration risk being associated with demographic factors (sex and age), BMI, type of caloric supplementation, chronic disease, and impaired mental status were significant contributing factors to low serum osmolality and inadequate total water intake. Although impaired mental status (cognition) can be a contributing factor for becoming dehydrated, it can also be an adverse outcome of dehydration. Being dehydrated can contribute to cognitive decline by negatively affecting short- and long-term memory, perceptions, and reaction time. Dehydration has also been associated with anxiety and agitation. In more severe cases, dehydration can precipitate hallucinations, delusions, and delirium.[40]

Strengths and Limitations

The primary strength of this study is that objective measures of hydration status (directly measured serum osmolality) and total water intake (trained research personnel weighed all food and beverages consumed within 24-hour periods) were acquired in subjects residing in several typical community-based LTC facilities. Directly measured serum osmolality assessed by freezing point depression is the optimal biomarker of hydration status because it is tightly controlled by homeostatic systems, and thus not as influenced by organ function or nutrient intake as other biomarkers such as BUN or BUN:creatinine. In addition, recognizing the increasing prevalence of overweight and obesity in LTC settings, the study design incorporated the range of BMI categories with height and weight directly measured by trained research personnel rather than relying on medical record documentation. Nevertheless, some limitations merit consideration. First, serum osmolality levels were not available for 46.6% of subjects. Yet, these subjects were not found to be statistically different with regard to key factors such as their age, sex, BMI, or functionality. Second, physical assessment of hydration status (eg, skin turgor, sunken eyes, or tongue dryness) was not performed, which might assist in defining dehydration or determining relationships between hydration status and total water intake. However, interpretation of hydration status from physical assessment can be misleading; being influenced by the aging process itself, these signs have low sensitivity and specificity, and thus are not considered to be reliable indicators.[41,42] In contrast, blood osmolality concentration has very low intra- and interindividual variation (1.3% and 1.5%, respectively).[43] Third, although the formulas used to determine adequacy of total water intake are frequently used in clinical practice, it is understood that there is limited evidence of their validity and reliability in the LTC population. Finally, the findings presented here may not be generalizable to all LTC residents because having a prescription for some form of caloric supplementation (between-meal snacks or ONS) was a requirement for study inclusion.

CONCLUSIONS

Dehydration continues to be a serious condition in LTC residents, regardless of their weight or BMI. Indeed, subjects with obesity are at high risk because they are less likely to be meeting their total water intake required for replacement of physiologic losses. This information has important implications with regard to future planning of nutrition care in LTC settings, as well as prevention of adverse outcomes and costly hospital admissions—especially as the prevalence of overweight and obesity increases in LTC settings. Further investigations using robust experimental methods are needed to determine the efficacy of strategies to maintain adequate hydration in various subgroups of LTC residents and to determine which strategies are most optimal for increasing total water intake and preventing dehydration. Whereas preventing or reversing dehydration likely requires intervention by multiple stakeholders, registered dietitian nutritionists (RDNs) could take a leadership role in designing and determining the efficacy of strategies. Such strategies could include routine evaluation of hydration status as part of the comprehensive nutrition assessment, identification of residents who are dehydrated or at high dehydration risk, and the provision of education by RDNs to other health care practitioners and LTC administrators regarding reliable indicators of dehydration in older adults. Moreover, investigation could focus on whether nutrition care plans that have a specific fluid intake goal, or at least a minimum daily total water intake such as 2,000 mL/day, prevent dehydration. Because the present study showed a relationship between total water intake with beverage consistency and type of ONS, RDNs could also determine the efficacy of strategies to increase water intake in residents consuming thickened beverages and higher caloric density ONS, and how to promote greater intake of the beverage types that have been shown to contribute most to total water intake.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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Table 1. Results from univariate analyses for associations with the outcomes of total water intake and serum osmolality in 247 long-term care residents participating in a study to determine relationships between hydration status, total water intake, and body mass index (BMI)

	Total Water Intake		Serum Osmolality	
Variable	***r* value**	***P* value**	***r* value**	***P* value**
Long-term care site[a]	0.14	0.25	0.10	0.91
Length of stay (mo)	−0.04	0.87	0.14	0.57
Age (y)	−0.24	0.003	0.10	0.63
Sex	0.17	0.004	0.10	0.38
Weight (kg)	0.33	<0.001	−0.17	0.34
BMI	0.24	0.005	−0.22	0.01
Has renal disease, yes or no	0.04	0.48	0.22	0.01
Has diabetes, yes or no	0.14	0.03	0.20	0.02
Eat/drink dependence[b]	−0.14	0.37	0.20	0.32
Total dependence[b]	−0.20	0.03	0.10	0.82
Mental status[c]	0.02	0.85	−0.32	0.004
Energy intake (kcal)	0.61	<0.001	0.10	0.64
Type of oral nutritional supplement[d]	0.36	0.002	0.48	0.001
Frequency of between-meal snack[e]	−0.10	0.40	0.10	0.86
Beverage consistency, thin or thick	−0.33	<0.001	0.05	0.60
Blood urea nitrogen (mg/dL)	−0.14	0.56	0.62	0.001
Blood urea nitrogen:creatinine	−0.22	0.11	0.30	0.006
Serum osmolality (μmol/L)	−0.17	0.22	N/A	N/A
Total water intake (g)	N/A[f]	N/A	−0.10	0.28

[a]Subjects were recruited from a total of eight community-based long-term—care sites.
[b]Based on Activities of Daily Living score from the most recent Minimum Data Set assessment; higher score indicates greater dependence.
[c]Based on Mini Mental State Exam; lower score indicates more severe cognitive impairment.
[d]Calorie-dense (>1.5 kcal/mL) vs standard formula.
[e]Three or two vs one snack per day.
[f]N/A=not available.

Table 2. Results from multivariate analyses for the outcome of total water intake in 247 long-term care residents participating in a study to determine relationships between hydration status, total water intake, and body mass index (BMI)

	Model 1: Adjusted R^2=0.55; P<0.001		Model 2: Adjusted R^2=0.56; P<0.001[a]	
Variable	Estimate±standard error	P value	Estimate±standard error	P value
Intercept	823.475±254.357	0.001	770.833±179.062	<0.001
Age (y)	−0.517±1.899	0.786		—
Sex	−87.989±52.836	0.097	−100.440±48.578	0.040
BMI	13.503±4.431	0.003	14.590±4.083	<0.001
Has diabetes, yes or no	53.812±44.917	0.232		—
Total dependence[b]	−9.056±3.915	0.022	−8.461±3.525	0.017
Mental status[c]	−0.374±2.854	0.896		—
Energy intake (kcal)	0.493±0.040	<0.001	0.505±0.038	<0.001
Type of oral nutritional supplement[d]	0.133±0.057	0.021	0.113±0.053	0.034
Type of liquid beverage, thin or thick	−414.163±67.494	<0.001	−420.791±66.220	<0.001

[a]Multivariable linear regression models; model 2 includes only those variables from model 1 that were statistically significant at α<.10.
[b]Activities of Daily Living score from the most recent Minimum Data Set assessment; higher score indicates greater dependence.
[c]Based on Mini Mental State Exam; lower score indicates more severe cognitive impairment.
[d]Calorie-dense (>1.5 kcal/mL) vs standard formula.

Table 3. Results from multivariate analyses for the outcome of serum osmolality in long-term care residents (n=128) participating in a study to determine relationships between hydration status, total water intake, and body mass index (BMI)

	Model 1: Adjusted R^2=0.45; P<0.001		Model 2: Adjusted R^2=0.46; P<0.001[a]	
Variable	Estimate±standard error	P value	Estimate±standard error	P value
Intercept	296.113±3.669	<0.001	291.862±1.463	<0.001
BMI	−0.102±0.139	0.467	—	—
Has renal disease, yes or no	0.315±1.590	0.843	—	—
Has diabetes, yes or no	2.112±1.294	0.100	1.761±1.236	0.157
Mental status[c]	−0.255±0.075	0.001	−0.295±0.069	<0.001
Type of oral nutritional supplement[d]	−0.002±0.002	0.231	—	—
Blood urea nitrogen (mg/dL)	0.442±0.058	<0.001	0.471±0.052	<0.001
Total water intake (g)	−0.001±0.001	0.412	—	—

[b]Activities of Daily Living score from the most recent Minimum Data Set assessment; higher score indicates greater dependence.
[a]Multivariable linear regression models; model 2 includes only those variables from model 1 that were statistically significant at α<.10.
[c]Based on Mini Mental State Exam; lower score indicates more severe cognitive impairment.
[d]Calorie-dense (>1.5 kcal/mL) vs standard formula.