Pre-meal Water Consumption Reduces Meal Energy Intake in Older but Not Younger Subjects

Emily L. Van Walleghen, Jeb S. Orr, Chris L. Gentile, and Brenda M. Davy

Abstract

VAN WALLEGHEN, EMILY, JEB S. ORR, CHRIS L. GENTILE, AND BRENDA M. DAVY. Pre-meal water consumption reduces meal energy intake in older but not younger subjects. *Obesity.* 2007;15:93–99.

Objective: To determine whether the consumption of water 30 minutes before an ad libitum meal reduces meal energy intake in young and older adults.

Research Methods and Procedures: Healthy, non-obese young ($n = 29$; age, 21 to 35 years) and older ($n = 21$; age, 60 to 80 years) individuals were provided with an ad libitum lunch meal on two occasions. Thirty minutes before the lunch meals, subjects were given either a water preload (WP: 375 mL, women; 500 mL, men) or no preload (NP). Energy intake at the two lunch meals was measured. Visual analog scales were used to assess changes in hunger, fullness, and thirst during the meal studies.

Results: There was no significant difference in meal energy intake between conditions in the young subjects (892 + 51 vs. 913 ± 54 kcal for NP and WP, respectively; $p = 0.65$). However, meal energy intake after the WP was significantly reduced relative to the NP condition in the older subjects (682 + 53 vs. 624 ± 56 kcal for NP and WP, respectively; $p = 0.02$). This effect was caused primarily by the reduction in meal energy intake after water consumption in older men. Hunger ratings were lower and fullness ratings were higher in older compared with younger adults ($p < 0.01$). Fullness ratings were higher in the WP condition compared with the NP condition for all subjects ($p = 0.01$). No age differences in thirst were detected during the test meals.

Discussion: Under acute test meal conditions, pre-meal water consumption reduces meal energy intake in older but not younger adults. Because older adults are at increased risk for overweight and obesity, intervention studies are needed to determine whether pre-meal water consumption is an effective long-term weight management strategy for the aging population.

Key words: water consumption, energy intake regulation, aging

Introduction

Recent estimates indicate that two thirds of the U.S. adult population is classified as either overweight or obese, and the prevalence of these conditions is higher in middle-aged and older adults (i.e., 71% to 73%) compared with the general population (1). In an effort to curtail progression of the obesity epidemic, much research has focused on identifying strategies to reduce meal energy intake, thereby preventing energy overconsumption and subsequent weight gain. One such strategy is to modify perceptions of hunger and fullness before a meal by consumption of a "preload" food or beverage. Low-energy, high-volume preloads, including specific formulations of soup and salad, reduce hunger and increase fullness before a meal and reduce overall energy intake (preload + ad libitum meal) compared with a no preload condition (ad libitum meal alone) (2–4). The effect of beverage consumption on ad libitum energy intake has also been of interest, because it has been suggested that liquids are less satiating than solids (5). Energy intake is higher under ad libitum meal conditions when energy-containing beverages (i.e., wine, beer, juice, milk, cola) are given before a meal or consumed with a meal compared with identical conditions when either water or no beverage is provided (6–8).

There is a common belief among the lay public that water ingestion will suppress hunger and reduce energy intake,

Received for review May 19, 2006.
Accepted in final form July 3, 2006.
The costs of publication of this article were defrayed, in part, by the payment of page charges. This article must, therefore, be hereby marked "advertisement" in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.
Department of Human Nutrition, Foods and Exercise, Virginia Polytechnic Institute and State University.
Address correspondence to Brenda M. Davy, Department of Human Nutrition, Foods and Exercise, 221 Wallace Hall (0430), Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.
E-mail: bdavy@vt.edu

thereby facilitating weight reduction. However, to our knowledge, there are no studies that directly address this issue. Water consumed with a meal reduces subjective ratings of hunger and increases ratings of satiety during a meal (9), but its effect on meal energy intake is not clear. Studies of beverage preloads and meal energy intake often use a water preload as the control condition; thus, a no preload condition is not available for comparison (10–17). Only one study is available that included both a water preload and no preload condition so that the effect of pre-meal water consumption on meal energy intake could be surmised. Rolls et al. (18) reported that young, normal-weight men consumed the same amount of energy at an ad libitum meal when given a water preload (8 and 16 oz) compared with no beverage 30 minutes before the meal (18). Given that changes in energy intake regulation have been reported with advancing age in both men and women (10,19,20) and that increased water consumption is frequently recommended to facilitate weight control, there is surprisingly little data addressing the effect of pre-meal water consumption on meal energy intake in healthy young and older adults.

Thus, the purpose of this study was to determine whether the consumption of water 30 minutes before an ad libitum meal affects perceptions of hunger and fullness and reduces meal energy intake in healthy men and women. Because aging is accompanied by changes in sensations of hunger and satiety (17,19) and in body weight (20–22), we also sought to determine whether aging influences the effect of water consumption on meal energy intake.

Research Methods and Procedures

Subjects

Healthy, non-obese (BMI $\leq$ 30 kg/m^2) young (age, 21 and 35 years) and older (age, 60 to 80 years) adults were recruited for this study. Subjects were weight stable ($\pm$2 kg for $>$1 year), non-smokers, free from cardiovascular and other chronic disease (diabetes, thyroid disorders, cancer, and heart, lung, and kidney disease), and not taking medications known to influence food intake or body weight. Individuals were excluded if they had impaired glucose tolerance (fasting plasma glucose $>$ 110 mg/dL). The older adults were screened for cardiovascular disease using resting and maximal exercise electrocardiograms before measurement of cardiorespiratory fitness (see below). Subjects were screened for dietary restraint (Eating Inventory cognitive restraint score $<$ 11) (23), depression (Centers for Epidemiological Studies Depression Scale score $<$ 35) (24), and eating disorders (Eating Attitudes Test score $<$ 20) (25), had no food allergies or restrictions, and did not consume alcohol in excess ($\leq$2 drinks/d). Forty young and 34 older adults were initially enrolled in this study; 11 young and 8 older subjects were unable to complete all study procedures because of time constraints or unwillingness to undergo certain study procedures (i.e., venipuncture, maximal exercise test), and 5 older subjects did not receive medical clearance to participate based on their resting/maximal exercise electrocardiograms. Our final sample included 29 young and 21 older individuals. All subjects provided informed consent before their participation in the study, but they were not aware of the specific purpose of the study. This protocol and consent form was approved by the Institutional Review Board at Virginia Polytechnic Institute and State University.

Measurements

Height was measured without shoes in meters using a wall-mounted stadiometer. Body mass was measured to the nearest 0.1 kg using a physician's balance scale. BMI was calculated as weight (kilograms) divided by height (meters) squared. Percentage body fat, absolute fat mass, and fat-free mass were measured using DXA (GE Lunar Prodigy; GE Healthcare, Madison, WI). Subjects were instructed in methods to accurately record their dietary intake; self-reported 4-day food intake records were used to determine habitual dietary intake. Energy and macronutrient intake were assessed using nutritional analysis software (NDS-R 5.0; University of Minnesota, Minneapolis, MN). Habitual physical activity level was determined by self-reported time (minutes per week) spent participating in moderate and vigorous physical activity. Cardiorespiratory fitness [maximal oxygen consumption ($V\text{O}_2$ max)][1] was determined by a graded exercise treadmill test to exhaustion using open-circuit spirometry (Parvo Medics 2400; Parvo Medics, Sandy, UT).

Procedures

Subjects reported to the laboratory for two lunch meals in random order as follows: 1) 30-minute waiting period (no preload) followed by an ad libitum meal and 2) preload consisting of 375 mL (women) or 500 mL (men) of water followed 30 minutes later by an ad libitum meal. Lunch meals for each subject were separated by a minimum of 2 days. The test meal was provided at lunchtime to replicate the experimental protocol used in other published work in this area (19,26). The 30-minute waiting period between water preload (WP) and meal was chosen because individuals compensate most accurately for the energy content of a preload when the preload is given 30 minutes before the lunch meal (26). Subjects were instructed to consume the WP as quickly as they comfortably could, within a maximum time period of 30 minutes. The amount of time taken to drink the preload was recorded by the study personnel. Subjects were asked to eat their usual breakfast meal at the

[1] Nonstandard abbreviations: $V\text{O}_2$ max, maximal oxygen consumption; SE, standard error; WP, water preload; VAS, visual analog scale(s); NP, no preload.

same time on both testing days (3,19) but to not eat anything for 3 hours before their study visit. They recorded their food intake on the morning of both testing days and for the remainder of the day after the test meal. During the meal studies, visual analog scales (VAS) were completed by subjects a total of six times at 30-minute intervals to rate sensations of fullness, hunger, and thirst: before the preload or 30-minute waiting period (0 minutes), before the lunch meal (30 minutes), after the lunch meal (60 minutes), and at 90, 120, and 150 minutes. Subjects were dismissed from the laboratory after completing the VAS scale at 150 minutes. The VAS consisted of a query ("How hungry are you right now?") and a 100-mm line that was anchored with descriptors that are polar opposites ("not at all hungry" to "extremely hungry"). Individuals were asked to make a mark on the line corresponding to their feelings. VAS are reproducible and valid indicators of hedonics in young and older populations (27–29). Reading was permitted during test meal sessions, but food- and diet-related content was screened and removed from all material.

Test Meals

All foods included in the test meal lunches were evaluated for palatability before initiation of the study. The lunch consisted of an individual buffet-style meal containing a variety of typical lunch items (e.g., bread, luncheon meat, cheese, lettuce, condiments, potato chips, carrots, applesauce, cookies, water) in excess of what would normally be consumed, from which the subjects were allowed to self-select over a 30-minute period. The WPs consisted of chilled tap water served at a constant temperature (5° to 7°C). Foods were weighed (±0.1 grams) before being served and again after the completion of the meal to determine the amount consumed. Meal energy and macronutrient intake were calculated using Nutrition Data System for Research nutritional analysis software. Young women were studied in the follicular phase of their menstrual cycles for both feeding conditions to minimize the effect of cycle phase on energy intake (30).

Statistical Analysis

Differences in demographic characteristics by age and sex were assessed using independent sample Student's t tests (SPSS v. 12.0 for Windows). Differences in energy intake, VAS ratings, and self-reported food intake on the morning of/remainder of the day after the test meals were assessed by repeated-measures ANOVA. Analysis of covariance was used to adjust for baseline differences between age groups in VAS data. Associations among variables were assessed by simple correlational analyses (Pearson's r). The α level was set a priori at $p < 0.05$.

Results

Participant demographic characteristics are listed in Table 1. BMI was not significantly different in the older compared with younger subjects (23.3 ± 0.5 vs. 24.7 ± 0.6 kg/m^2, $p > 0.05$), but body fat was higher in the older subjects (30.5 ± 1.8% vs. 22.6 ± 1.6%, $p < 0.01$). Restraint scores were higher in older subjects relative to their younger counterparts (7.7 ± 0.7 vs. 5.3 ± 0.6, $p < 0.01$). There were no significant differences in habitual dietary intake (energy; percent kilocalories from fat, carbohydrate, protein, or alcohol) between older and younger subjects in our sample, but young women reported a lower energy and protein intake than younger men (Table 1). Self-reported water consumption was lower in older than in younger subjects (469 ± 118 vs. 905 ± 155 grams, $p = 0.03$), but habitual total beverage consumption (all beverages, including water) was not significantly different between age groups (1713 ± 151 vs. 1771 ± 147 grams, $p = 0.79$). Habitual water consumption did not differ between men and women within age groups (i.e., young men vs. young women and older men vs. older women; both $p > 0.05$), but sex differences in self-reported beverage consumption within age groups were noted. In both the young and older groups, mean beverage consumption was ~600 grams higher in men compared with women (older: 1995 ± 256 vs. 1406 ± 93 grams, $p = 0.05$; young: 2131 ± 241 vs. 1433 ± 130 grams, $p = 0.02$). Habitual physical activity level did not differ by age or sex group. As would be expected with advancing age, $\dot{V}O_2$ max was lower in older compared with younger subjects (28.2 ± 1.8 vs. 46.2 ± 2.2 mL/kg per minute, $p < 0.01$).

Energy intake during the two test meals in young and older subjects is shown in Figure 1. Neither the condition effect ($p = 0.47$) nor the condition-by-age group interaction effect ($p = 0.16$) was significant, but meal energy intake was lower in older compared with younger adults ($p = 0.02$). When the younger subjects were considered in a separate analysis, there was no significant condition effect [Figure 1; 892 ± 51 vs. 913 ± 54 at no preload (NP) and WP, respectively; $p = 0.65$] or sex-by-condition interaction effect ($p = 0.57$). In contrast, meal energy intake after the WP was significantly reduced relative to the NP condition in the older subjects by ~60 kcal (Figure 1; 682 ± 53 vs. 624 ± 56 kcal for NP and WP, respectively; $p = 0.02$). The reduction in meal energy intake after water consumption in older adults was caused primarily by a significantly greater reduction in older men compared with women (111 ± 37 vs. 4 ± 25 kcal, $p = 0.03$). The difference in energy intake between the two meal conditions was not associated with either habitual water ($p = 0.11$) or beverage ($p = 0.10$) consumption. There were no significant differences in meal macronutrient composition (percentage total energy) or in water consumption (excluding the WP) by age or condition (data not shown, all $p > 0.05$). The time taken to consume the WP was also not significantly different between older and younger subjects (13 ± 2 vs. 12 ± 2 minutes, $p = 0.65$).

Table 1. Subject characteristics*

	Young men ($n = 14$)	Young women ($n = 15$)	Older men ($n = 11$)	Older women ($n = 10$)
Age (years)	26 ± 1	23 ± 1†	68 ± 2†	69 ± 2§
Height (cm)	176 ± 2	165 ± 2†	175 ± 2	163 ± 2‡
Weight (kg)	76.5 ± 2.1	59.8 ± 1.4†	75.4 ± 2.9	65.7 ± 2.8‡§
BMI (kg/m^2)	24.8 ± 0.7	21.9 ± 0.5†	24.6 ± 0.7	24.7 ± 0.9§
Body fat (%)	16.6 ± 2.2	27.5 ± 1.5†	24.9 ± 1.9†	37.2 ± 1.8‡§
Dietary restraint score	4.4 ± 0.7	6.1 ± 0.8	6.7 ± 0.9†	8.9 ± 1.0§
Habitual dietary intake				
Energy (kcal)	2503 ± 201	1901 ± 140†	2203 ± 170	1819 ± 108
Fat (% energy)	30 ± 2	29 ± 2	33 ± 2	33 ± 2
Carbohydrate (% energy)	51 ± 2	56 ± 2	51 ± 2	51 ± 3
Protein (% energy)	17 ± 1	14 ± 1†	15 ± 1	16 ± 1§
Alcohol (% energy)	1 ± 1	3 ± 1	3 ± 1	1 ± 1
Water consumption (g)	1214 ± 276	616 ± 122	519 ± 197	414 ± 132†
Total beverage consumption, g	2131 ± 241	1433 ± 130†‡	1995 ± 256	1406 ± 93†‡
Habitual physical acivity (min/wk)	382 ± 121	249 ± 83	401 ± 131	281 ± 138
VO_2 max (ml/kg/min)	52.9 ± 3.5	40.3 ± 2.0†	33.0 ± 2.3†	22.5 ± 1.7‡§

* Data are expressed as mean ± SE.
† Significantly different from young men, $p < 0.05$.
‡ Significantly different from older men, $p < 0.05$.
§ Significantly different from young women, $p < 0.05$.

Self-reported breakfast intake on the day of the test meals (298 ± 41 vs. 330 ± 35 kcal for NP and WP, respectively; $p = 0.24$) and intake during the remainder of the day after the test meals (1160 ± 103 vs. 1064 ± 67 kcal for NP and WP, respectively; $p = 0.39$) were not significantly different between meal conditions or age groups.

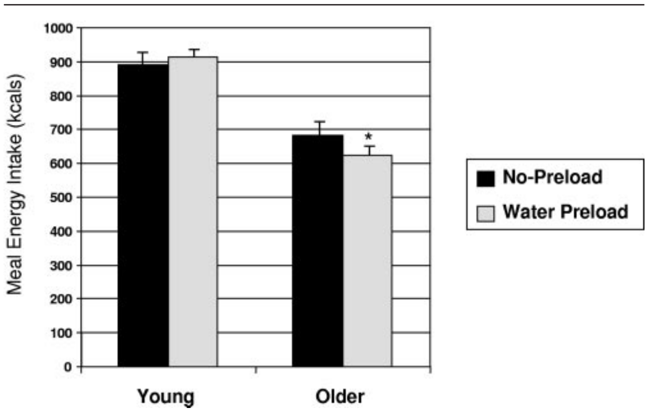

Figure 1: Energy intake at ad libitum test meals after WP vs. NP. *Significant reduction in meal energy intake after the WP compared with the NP condition in older adults ($p = 0.02$).

Baseline hunger and thirst (average of both conditions, time 0) were significantly lower in the older compared with younger adults (hunger: 24 ± 4 vs. 40 ± 3, $p = 0.003$; thirst: 31 ± 5 vs. 45 ± 4, $p = 0.02$), but there was no difference in baseline fullness (50 ± 3 vs. 46 ± 2, $p = 0.38$). As expected, hunger, fullness, and thirst changed significantly with time in response to meal ingestion (Figures 2–4). There was no significant difference in hunger ratings between test meals (Figure 2), but hunger ratings during both test meals were significantly lower in the older compared with younger subjects ($p = 0.006$), and there was a significant condition-by-time-by-age group interaction ($p = 0.03$). There was a significant difference in fullness between meal conditions (Figure 3); subjects reported more fullness in the WP condition than in the NP condition (57 ± 2 vs. 51 ± 2 mm, $p = 0.01$). In addition, older subjects reported more fullness than younger subjects during the WP condition (63 ± 3 vs. 51 ± 2 mm, $p = 0.002$) and more fullness overall (56 ± 3 vs. 52 ± 2 mm, $p = 0.002$). In response to the WP, older adults reported significantly more fullness than younger adults (change in VAS rating from 0 to 30 minutes: 9 ± 6 vs. 1 ± 2 mm, $p = 0.001$). After adjustment for baseline thirst, there was no significant difference in ratings of thirst between conditions, but there was

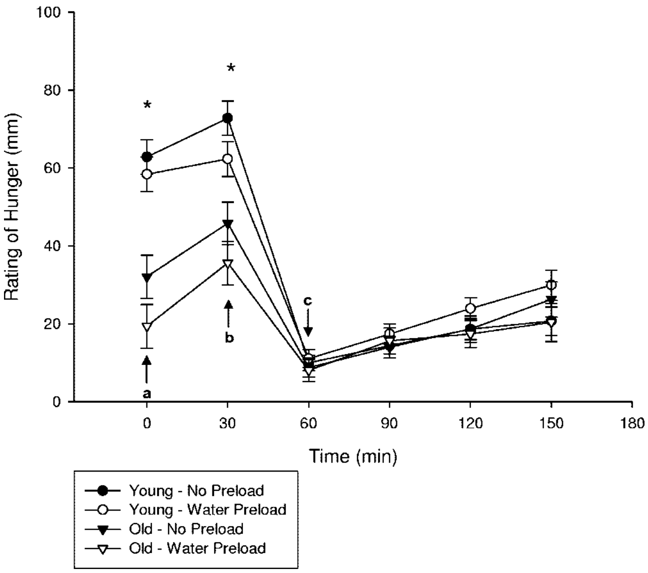

Figure 2: Mean ± SE ratings of hunger in the NP and WP conditions in young and older adults. The WP was given immediately after completion of the 0-minute VAS (a). Subjects completed a second VAS at 30 minutes (b) and were immediately provided with the ad libitum meal. After completion of the meal at 60 minutes, subjects completed a third VAS (c). There was a significant difference in hunger between age groups ($p = 0.006$) in all subjects over time ($p < 0.001$), and a condition-by-time-by-age group interaction ($p = 0.03$), which persisted after adjusting for baseline differences in hunger. *Significant condition-by-age group difference.

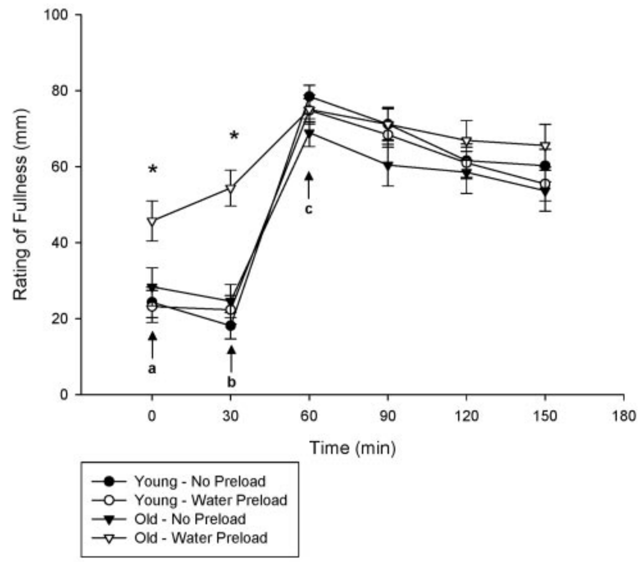

Figure 3: Mean ± SE ratings of fullness in the NP and WP conditions in young and older adults. The WP was given immediately after completion of the 0-minute VAS (a). Subjects completed a second VAS at 30 minutes (b) and were immediately provided with the ad libitum meal. After completion of the meal at 60 minutes, subjects completed a third VAS (c). There was a significant difference in fullness between conditions ($p = 0.01$) and in all subjects over time ($p < 0.001$). Older adults reported significantly more fullness than younger adults overall ($p = 0.002$) and in the WP condition ($p = 0.002$). *Significant condition-by-age group difference.

a significant condition-by-time interaction ($p = 0.002$; Figure 4). No significant age difference in thirst was noted during the test meals, and there were no significant sex differences in ratings of hunger, fullness, or thirst (data not shown).

No significant associations were noted between dietary cognitive restraint, BMI, percentage body fat, habitual physical activity level, and cardiovascular fitness and difference in energy intake between test meal conditions (data not shown).

Discussion

The major finding of this study is that pre-meal water consumption significantly reduced meal energy intake in older, but not younger, adults. This effect was particularly pronounced among the older men, who consumed ~111 fewer kcal at the ad libitum meal after the WP relative to an NP condition. In the group as a whole, subjective ratings of fullness were significantly higher in the WP condition relative to the NP condition, but only in the older adults did this correspond to a reduction in meal energy intake. Our finding that pre-meal water does not reduce meal energy intake in young adults is consistent with observations by Rolls et al. (18). Our results extend these findings by suggesting that pre-meal water does not influence meal energy intake in young women. Despite the common belief that increased water consumption facilitates weight control by reducing meal energy intake, our observations in young adults are not consistent with this postulate.

High water consumption has been linked to a lower energy intake and healthier dietary patterns in population-based studies (31). Popkin et al. (31) recently reported that the daily energy intake of water consumers (mean water intake of 51.9 oz/d) was 194 kcal lower than that of non-consumers of water and that older adults were more likely to have a high water consumption. Our finding that pre-meal water consumption significantly reduced meal energy intake in older adults suggests that this may be an effective weight control strategy for this segment of the population. If the reduction in energy intake in this sample of older adults was extrapolated to three meals per day, this would represent ~180 kcal, which is similar to the lower energy intake reported by Popkin et al. (30) in water consumers. However, long-term intervention studies must be conducted to address this possibility. Because recent data indicate that adults ≥60 years of age have a higher prevalence of overweight and obesity (71%) than the general population (1), such studies in older adults are warranted.

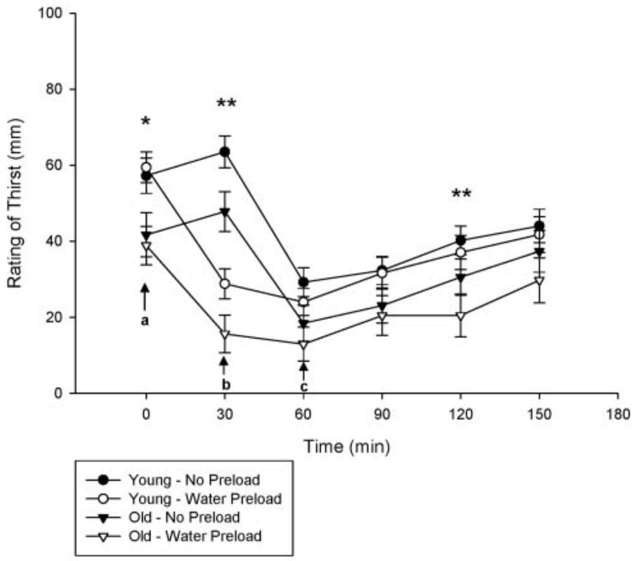

Figure 4: Mean ± SE ratings of thirst in the NP and WP conditions in young and older adults. The WP was given immediately after completion of the 0-minute VAS scale (a). Subjects completed a second VAS scale at 30 minutes (b) and were immediately provided with the ad libitum meal. After completion of the meal at 60 minutes, subjects completed a third VAS scale (c). After adjusting for baseline age-group differences in thirst (*), there were no significant differences in thirst between older and young adults. **Significant difference in conditions.

There are several possible reasons why pre-meal water consumption reduced meal energy intake in older adults. Previous work has shown that aging is associated with reductions in the gastric emptying time of both solids and liquids (32). Clarkston et al. (32) reported that the gastric emptying time (time for 50% of the stomach contents to empty) for a 150-mL low-nutrient (67 kcal) liquid was ~34% longer in older adults compared with younger adults (47 ± 4 vs. 35 ± 3 minutes in older and younger adults, respectively; $p < 0.05$). Other investigators have shown age-related differences in antral area and plasma cholecystokinin after the ingestion of liquid preloads (17). Sensory changes are also known to occur with advancing age (33). Consistent with previous observations in older adults (17,19,34), our results indicate that healthy older adults report less hunger and more fullness in response to a meal. Thus, changes in gastrointestinal physiology and sensations of hunger/fullness with aging may explain the reduction in meal energy intake after water consumption.

It is not likely that differences in habitual fluid intake in young and older adults explain our findings. While older adults may be more likely to be water consumers than young adults (31), previous reports do not suggest that overall habitual fluid intake differs with advancing age (35). We also did not find age-related differences in habitual beverage intake in our sample of healthy older adults, and our mean beverage intake data are comparable with what has been previously reported in young and older adults (35). Furthermore, the difference in energy intake between test meal conditions was not associated with either habitual water or beverage consumption. It is possible that beverage temperature could influence meal energy intake and/or subjective sensations of hunger and satiety in older adults, but we are not aware of any data addressing this issue. However, beverage temperature does not significantly affect gastric emptying rate in middle-aged adults (36).

Alterations in thirst regulatory mechanisms have been reported in response to water deprivation in older adults (37). The older adults in our sample reported less thirst at baseline than the young adults, but after accounting for these baseline differences, no age-related differences in thirst were noted in response to the test meals. De Castro (35) did not detect impairments in subjective thirst sensations in healthy, free-living older adults; thus, it does not seem likely that differences in thirst sensitivity with age explain our findings.

There are some limitations of this study that should be acknowledged. Our results are limited to an acute meal setting. Thus, it is uncertain whether the reduction in meal energy intake after water consumption in older adults would be sustained over time. Long-term intervention studies are needed to address this issue. Also, we did not control food intake on the morning of our lunch meals. However, reported breakfast energy intake was not different between conditions. Our sample size was relatively small; future studies with greater subject numbers are needed to confirm our findings. Finally, our findings should not be extrapolated beyond the age ranges studied.

In conclusion, our results suggest that, under acute test meal conditions, pre-meal water consumption reduces meal energy intake in older but not younger adults. These differences may be caused by age-related changes in gastrointestinal physiology and perceptions of hunger and fullness. Our data also suggest that a WP may not be an appropriate "control" condition for food intake studies using a preloading paradigm, at least in older adults, because a WP may alter food intake despite being non-caloric. Additionally, older adults who are at nutritional risk (i.e., anorexia of aging) should refrain from consuming significant amounts of water before meal consumption. Because older adults are at increased risk for overweight and obesity (1), future intervention studies should be conducted to determine whether pre-meal water consumption is an effective long-term weight management strategy for the aging population.

Acknowledgments

The authors do not have any conflicts of interest to disclose. This study was supported by the Virginia Tech/University of Virginia/Carilion Biomedical Institute Collaborative Research Grants Program.

References

1. **Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM.** Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA.* 2006;295:1549–55.
2. **Rolls BJ, Bell EA, Castellanos VH, Chow M, Pelkman CL, Thorwart ML.** Energy density but not fat content of foods affected energy intake in lean and obese women. *Am J Clin Nutr.* 1999;69:863–71.
3. **Rolls BJ, Fedoroff IC, Guthrie JF, Laster LJ.** Foods with different satiating effects in humans. *Appetite.* 1990;15:115–26.
4. **Rolls BJ, Roe LS, Meengs JS.** Salad and satiety: energy density and portion size of a first-course salad affect energy intake at lunch. *J Am Diet Assoc.* 2004;104:1570–6.
5. **Almiron-Roig E, Chen Y, Drewnowski A.** Liquid calories and the failure of satiety: how good is the evidence? *Obes Rev.* 2003;4:201–12.
6. **Westerterp-Plantenga MS, Verwegen CR.** The appetizing effect of an aperitif in overweight and normal-weight humans. *Am J Clin Nutr.* 1999;69:205–12.
7. **Almiron-Roig E, Drewnowski A.** Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav.* 2003;79:767–73.
8. **DellaValle DM, Roe LS, Rolls BJ.** Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? *Appetite.* 2005;44:187–93.
9. **Lappalainen R, Mennen L, van Weert L, Mykkanen H.** Drinking water with a meal: a simple method of coping with feelings of hunger, satiety and desire to eat. *Eur J Clin Nutr.* 1993;47:815–9.
10. **Boudville A, Bruce DG.** Lack of meal intake compensation following nutritional supplements in hospitalised elderly women. *Br J Nutr.* 2005;93:879–84.
11. **Canty DJ, Chan MM.** Effects of consumption of caloric vs noncaloric sweet drinks on indices of hunger and food consumption in normal adults. *Am J Clin Nutr.* 1991;53:1159–64.
12. **Cecil JE, Palmer CN, Wrieden W, et al.** Energy intakes of children after preloads: adjustment, not compensation. *Am J Clin Nutr.* 2005;82:302–8.
13. **de Graaf C, Hulshof T.** Effects of weight and energy content of preloads on subsequent appetite and food intake. *Appetite.* 1996;26:139–51.
14. **Holt SH, Sandona N, Brand-Miller JC.** The effects of sugar-free vs sugar-rich beverages on feelings of fullness and subsequent food intake. *Int J Food Sci Nutr.* 2000;51:59–71.
15. **Lavin JH, French SJ, Read NW.** The effect of sucrose- and aspartame-sweetened drinks on energy intake, hunger and food choice of female, moderately restrained eaters. *Int J Obes Relat Metab Disord.* 1997;21:37–42.
16. **Rodin J.** Comparative effects of fructose, aspartame, glucose, and water preloads on calorie and macronutrient intake. *Am J Clin Nutr.* 1990;51:428–35.
17. **Sturm K, Parker B, Wishart J, et al.** Energy intake and appetite are related to antral area in healthy young and older subjects. *Am J Clin Nutr.* 2004;80:656–67.
18. **Rolls BJ, Kim S, Fedoroff IC.** Effects of drinks sweetened with sucrose or aspartame on hunger, thirst and food intake in men. *Physiol Behav.* 1990;48:19–26.
19. **Rolls BJ, Dimeo KA, Shide DJ.** Age-related impairments in the regulation of food intake. *Am J Clin Nutr.* 1995;62:923–31.
20. **Roberts SB, Fuss P, Heyman MB, et al.** Control of food intake in older men. *JAMA.* 1994;272:1601–6.
21. **Flegal KM, Carroll MD, Ogden CL, Johnson CL.** Prevalence and trends in obesity among US adults, 1999–2000. *JAMA.* 2002;288:1723–7.
22. **Newman AB, Lee JS, Visser M, et al.** Weight change and the conservation of lean mass in old age: the Health, Aging and Body Composition Study. *Am J Clin Nutr* 2005;82:872–8.
23. **Stunkard AJ, Messick S.** The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res.* 1985;29:71–83.
24. **Garner DM, Olmsted MP, Bohr Y, Garfinkel PE.** The eating attitudes test: psychometric features and clinical correlates. *Psychol Med.* 1982;12:871–8.
25. **Radloff L.** The CES-D scale: a self-report depression scale for research in the general population. *Applied Psych Meas.* 1977; 1:385–401.
26. **Rolls BJ, McDermott TM.** Effects of age on sensory-specific satiety. *Am J Clin Nutr.* 1991;54:988–96.
27. **Flint A, Raben A, Blundell JE, Astrup A.** Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *Int J Obes Relat Metab Disord.* 2000;24:38–48.
28. **Parker BA, Sturm K, MacIntosh CG, Feinle C, Horowitz M, Chapman IM.** Relation between food intake and visual analogue scale ratings of appetite and other sensations in healthy older and young subjects. *Eur J Clin Nutr.* 2004;58:212–8.
29. **Porrini M, Crovetti R, Testolin G, Silva S.** Evaluation of satiety sensations and food intake after different preloads. *Appetite.* 1995;25:17–30.
30. **Buffenstein R, Poppitt SD, McDevitt RM, Prentice AM.** Food intake and the menstrual cycle: a retrospective analysis, with implications for appetite research. *Physiol Behav.* 1995; 58:1067–77.
31. **Popkin BM, Barclay DV, Nielsen SJ.** Water and food consumption patterns of U.S. adults from 1999 to 2001. *Obes Res.* 2005;13:2146–52.
32. **Clarkston WK, Pantano MM, Morley JE, Horowitz M, Littlefield JM, Burton FR.** Evidence for the anorexia of aging: gastrointestinal transit and hunger in healthy elderly vs. young adults. *Am J Physiol.* 1997;272:R243–8.
33. **Rolls BJ.** Aging and appetite. *Nutr Rev.* 1992;50:422–6.
34. **Parker BA, Chapman IM.** Food intake and ageing—the role of the gut. *Mech Ageing Dev.* 2004;125:859–66.
35. **de Castro JM.** Age-related changes in natural spontaneous fluid ingestion and thirst in humans. *J Gerontol.* 1992;47:P321–30.
36. **Shi X, Bartoli W, Horn M, Murray R.** Gastric emptying of cold beverages in humans: effect of transportable carbohydrates. *Int J Sport Nutr Exerc Metab.* 2000;10:394–403.
37. **Phillips PA, Rolls BJ, Ledingham JG, et al.** Reduced thirst after water deprivation in healthy elderly men. *N Engl J Med.* 1984;311:753–9.