Inadequate Hydration, BMI, and Obesity Among US Adults: NHANES 2009-2012

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ABSTRACT

PURPOSE Improving hydration is a strategy commonly used by clinicians to prevent overeating with the goal of promoting a healthy weight among patients. The relationship between weight status and hydration, however, is unclear. Our objective was to assess the relationship between inadequate hydration and BMI and inadequate hydration and obesity among adults in the United States.

METHODS Our study used a nationally representative sample from the National Health and Nutrition Examination Survey (NHANES) 2009 to 2012, and included adults aged 18 to 64 years. The primary outcome of interest was body mass index (BMI), measured in continuous values and also categorized as obese (BMI ≥30) or not (BMI <30). Individuals with urine osmolality values of 800 mOsm/kg or greater were considered to be inadequately hydrated. Linear and logistic regressions were performed with continuous BMI and obesity status as the outcomes, respectively. Models were adjusted for known confounders including age, race/ethnicity, sex, and income-to-poverty ratio.

RESULTS In this nationally representative sample (n = 9,528; weighted n = 193.7 million), 50.8% were women, 64.5% were non-Hispanic white, and the mean age was 41 years. Mean urine osmolality was 631.4 mOsm/kg (SD = 236.2 mOsm/kg); 32.6% of the sample was inadequately hydrated. In adjusted models, adults who were inadequately hydrated had higher BMIs (1.32 kg/m^2; 95% CI, 0.85-1.79; P <.001) and higher odds of being obese (OR = 1.59; 95% CI, 1.35-1.88; P <.001) compared with hydrated adults.

CONCLUSION We found a significant association between inadequate hydration and elevated BMI and inadequate hydration and obesity, even after controlling for confounders. This relationship has not previously been shown on a population level and suggests that water, an essential nutrient, may deserve greater focus in weight management research and clinical strategies.

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INTRODUCTION

Obesity continues to be a prevalent, debilitating, and costly chronic disease in most high-income countries.[1] The drivers of obesity are multifactorial and represent a major clinical challenge in both prevention and management.[2,3] In addition to replacing sugar-sweetened beverages with water, improving overall hydration is a strategy commonly used to prevent overeating, with the goal of promoting a healthy weight among patients.[4-6] For example, counseling patients to first drink water when they have the urge to eat, as they may actually be thirsty rather than hungry, is a recommendation clinicians give patients and is advice readily found in lay media.

Water intake as a weight loss tool, however, is not an evidence-based recommendation. Recent studies have shown mixed results, likely because of limitations in the measurement of hunger and thirst, as well as the numerous social, cognitive, sensory, and logistical factors that influence eating and drinking behaviors.[5] Some studies suggest that water intake may be a promising target for obesity prevention and treatment, whereas

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other studies report an association between obesity and greater water intake.[7,8]

A recent systematic review reported contradictory findings between water intake and obesity among the 6 cross-sectional studies investigated, with some studies even showing a direct relationship between water intake and obesity.[8] The authors hypothesized that obese individuals may consume food with higher salt content, driving the need for increased water intake to balance the renal solute load.[8] Although these cross-sectional studies of water intake and obesity have shown mixed results, results from recent longitudinal studies and randomized controlled trials indicate the potential for water to prevent and treat obesity effectively.[4,9] Findings from 3 prospective cohort studies (the Nurses' Health Study I and II, and the Health Professionals Follow-Up Study) indicate that greater water intake is inversely associated with weight gain.[10]

Among these studies, water intake has been the outcome of interest.[4,8-10] Urine osmolality, however, is a more effective measure of hydration than water intake alone, as it accounts for water and solutes acquired in food and other beverages.[11] Urine osmolality also measures daily water intake more accurately because it is an objective laboratory measurement that is not subject to recall bias. In 2009, the National Health and Nutrition Examination Survey (NHANES) added urine osmolality as a laboratory test for its sample. To date, no population-level studies have investigated the relationship between adequate hydration, as measured by urine osmolality, and obesity. The aim of this study was to use the NHANES to assess the relationship between urine osmolality as a marker for hydration and obesity (based on body mass index, BMI) among adults in the United States.

METHODS

The NHANES is a program of studies designed to assess the health and nutritional status of adults and children in the United States. This survey is unique in that it combines interviews and physical examinations. Data from the 2 most recent NHANES cohorts (2009 to 2010 and 2011 to 2012) were used for all analyses.[12] Adults aged 18 to 64 years with complete medical examination data were included in the analysis. To make a collection of participants selected under the complex NHANES survey design representing the US noninstitutionalized civilian population, each sampled person is assigned a numerical sample weight. All analyses were performed using appropriate complex survey weights with STATA 13.1 (StataCorp LP). The University of Michigan institutional review board determined this study to be not regulated.

The primary outcome of interest was BMI (kg/m^2), which was used to further categorize individuals as obese (BMI ≥30) or not (BMI <30).[13] Urine osmolality information collected at the medical examination was used to determine hydration status. Consistent with previous studies and recommendations, individuals with values of 800 mOsm/kg or greater were considered inadequately hydrated.[11,14-16] Bivariate associations between hydration and covariates were performed using independent samples *t* test and Pearson χ^2, as appropriate. Models were adjusted for known confounders including age, race/ethnicity, sex, and income-to-poverty ratio.[17,18] To determine income-to-poverty ratio, participants were asked to report the total (annual) income for themselves and for other members of their family. Family income was then divided by the poverty threshold, which is adjusted for family size and is updated annually for inflation. An income-to-poverty ratio less than 1 indicates that the family is below the poverty threshold.

Linear and logistic regressions were performed with continuous BMI and obesity status (obese/not obese) as the outcomes, respectively. To determine whether associations between BMI and hydration status changed with age, interactions between hydration status and age were investigated in both the linear and logistic regression models. All findings are reported with sampling weights applied, unless otherwise noted.

To ensure that results were not influenced by factors known to alter urine osmolality, a sensitivity analysis was performed on the final models. We identified individuals who had a known diagnosis of diabetes, who had an elevated glycohemoglobin level (6.5% or greater), or who were currently prescribed a diuretic and reestimated the final models excluding these cases.

Of note, hydration status is dependent on water intake via consumption of food and fluids, as well as on water production, which is influenced by physical activity among other factors, and they are intermediate in the proposed pathway linking BMI and hydration. Accordingly, we did not adjust for fluid intake or physical activity to avoid overadjustment in our models.

RESULTS

After combining data from the NHANES 2009-2010 and 2011-2012 surveys, we had an unweighted sample size of 9,528 individuals (weighted n = 193.7 million) aged 18 to 64 years with complete medical examination data. Table 1 displays the demographic characteristics of the sample. Approximately 50.8% were women, 64.5% were non-Hispanic white, their mean age was 41.1 years.

The mean urine osmolality was 631.4 mOsm/kg (SD = 236.2 mOsm/kg), with 32.6% inadequately

hydrated based on a urine osmolality of 800 mOsm/kg or greater. In bivariate analyses, hydration status was significantly associated with age, race/ethnicity, sex, income-to-poverty ratio, and BMI (Table 2).

In multivariable analyses, hydration status was significantly associated with BMI outcomes in both linear and logistic regression models (Table 3). Adults who were inadequately hydrated had a mean BMI of 1.32 kg/m^2 (95% CI, 0.85-1.79 kg/m^2; P <.001) more than hydrated individuals, on average. The odds of being obese were 1.59 times higher for inadequately hydrated individuals compared with hydrated individuals (95% CI, 1.35-1.88; P <.001).

As expected, race/ethnicity, income-to-poverty ratio, and age were also significantly associated with BMI outcomes in adjusted models. Mexican Americans and non-Hispanic blacks were more likely to be obese and have higher BMIs than non-Hispanic whites, whereas other races were less likely. Older adults also had higher BMIs and were more likely to be obese than younger adults. Individuals with higher income-to-poverty ratios were significantly less likely to have higher BMIs and less likely to be obese than individuals with lower income-to-poverty ratios. No significant interactions were found between hydration status and age in either linear or logistic regressions.

In this sample, 1,536 individuals had known diabetes (n = 807), had an elevated glycohemoglobin (n = 242), or were prescribed a diuretic (n = 487). A sensitivity analysis that used models excluding this subset of individuals resulted in findings similar to those of the models above. Inadequately hydrated individuals had higher mean BMIs (1.44 kg/m^2; 95% CI, 1.02-1.87 kg/m^2; P <.001) and were also more likely to be obese (adjusted odds ratio = 1.67; 95% CI, 1.40-1.99; P <.001) than adequately hydrated individuals. Race, age, and income-to-poverty ratio effects on BMI and obesity were also similar in models excluding this group (data not shown).

Table 1. Demographic Characteristics of US Adults Aged 18 to 64 Years, NHANES 2009-2012

Characteristic	Unweighted	Weighted
Age, y[a]		
18-24, No (%)	1,653 (17.4)	14.9
25-30, No (%)	1,136 (11.9)	12.8
31-40, No (%)	1,942 (20.4)	20.4
41-50, No (%)	1,951 (20.5)	22.3
51-64, No (%)	2,846 (29.9)	29.6
Mean (SD), y	40.8 (14.1)	41.1 (11.7)
Race/ethnicity[a]		
Mexican American, No (%)	1,541 (16.2)	9.2
Other Hispanic, No (%)	1,019 (10.7)	6.2
Non-Hispanic white, No (%)	3,645 (38.3)	64.5
Non-Hispanic black, No (%)	2,201 (23.1)	12.2
Other, No (%)[b]	1,122 (11.8)	7.9
Sex[a]		
Male, No (%)	4,656 (48.9)	49.2
Female, No (%)	4,872 (51.1)	50.8
Income-to-poverty ratio[c]		
<1 (<100% federal poverty level)	2,308 (26.6)	17.9
Mean (SD) ratio	2.4 (1.7)	2.9 (1.4)

Note: unweighted N = 9,528; weighted n = 193.7 million.

[a] N = 9,528.

[b] Includes Asian, Native American, multiracial, and all other populations.

[c] n = 8,680.

Table 2. Bivariate Relationships Between Hydration Status and Participants' Characteristics

Characteristic	Adequately Hydrated[a] (67.4%, Weighted)	Inadequately Hydrated[b] (32.6%, Weighted)
Age, mean (SD), y[c]	43 (12)	37 (12)
Race/ethnicity[d]		
Mexican American, %	7.8	12.0
Other Hispanic, %	5.4	7.8
Non-Hispanic white, %	68.4	57.8
Non-Hispanic black, %	10.4	15.0
Other, %[e]	8.1	7.5
Sex[d]		
Male, %	46.0	59.1
Female, %	54.0	40.9
Income-to-poverty ratio, mean (SD)[c]	3.0 (1.5)	2.8 (1.5)
BMI, mean (SE)[c,d]	28.3 (0.15)	29.2 (0.20)
Obese, %[f]	67.7	59.7
Not obese, %[g]	32.3	40.3

BMI = body mass index; SE = standard error.

[a] Urine osmolality <800 mOsm/kg.

[b] Urine osmolality ≥800 mOsm/kg.

[c] Compared using independent samples t test, all P <.001.

[d] Compared using Pearson χ^2 test, all P <.001.

[e] Includes Asian, Native American, multiracial, and all other populations.

[f] BMI ≥30.

[g] BMI <30.

DISCUSSION

In this nationally representative, recent sample of US adults, inadequate hydration was associated with higher BMI and obesity among adults aged 18 to 64 years. Our study highlights a novel relationship between hydration and BMI that may have important clinical implications.

Table 3. Results of Linear and Logistic Regression Models

Variable	Linear Regression: Continuous BMI β (95% CI)	Logistic Regression: BMI ≥30 OR (95% CI)
Inadequate hydration	1.32 (0.85 to 1.79)[a]	1.59 (1.35 to 1.88)[a]
Sex		
Female	Reference	Reference
Male	0.21 (–0.12 to 0.53)	1.09 (0.96 to 1.25)
Race/ethnicity		
Non-Hispanic white	Reference	Reference
Mexican American	1.02 (0.42 to 1.62)[b]	1.40 (1.17 to 1.66)[a]
Other Hispanic	0.39 (–0.17 to 0.95)	1.15 (0.94 to 1.42)
Non-Hispanic black	2.32 (1.76 to 2.88)[a]	1.76 (1.48 to 2.09)[a]
Other	–2.11 (–2.73 to –1.49)[a]	0.49 (0.38 to 0.62)[a]
Income-to-poverty ratio	–0.28 (–0.44 to –0.13)[b]	0.93 (0.89 to 0.97)[b]
Age	0.09 (0.07 to 0.11)[a]	1.02 (1.01 to 1.03)[a]

BMI = body mass index; OR = odds ratio.

[a] $P < .001$.

[b] $P < .01$.

Although causality and directionality cannot be established in our cross-sectional study, our findings suggest that additional investigation is warranted to examine the relationship between inadequate hydration and weight status. Inadequate hydration has been associated with worsened mental, physical, and emotional health.[19] Performance in tasks that require attention, psychomotor, and immediate memory skills may be affected.[20,21] Self-ratings of alertness and ability to concentrate have been shown to decline while ratings of tiredness and headache increase progressively when fluid intake is restricted to induce deficits of even as little as 1% to 2%.[21] Poor mood, headaches, and renal dysfunction, as well as constipation, have also been associated with inadequate hydration.[11,22]

Though hydration is discussed in the context of weight management by clinicians and lay media, recommendations to remain adequately hydrated are not included in generally accepted guidelines as a treatment in weight management.[23] Our findings suggest that adequate hydration may play a role in weight and prompt further discussion regarding adequate hydration during weight management counseling. If obese individuals are more likely to maintain poor hydration or are eating when they are actually thirsty, additional education could be provided regarding differentiating between cues of hunger and thirst.

Our findings also suggest that individuals with higher BMIs may behave in ways that lead them to be inadequately hydrated. Obese individuals have higher water needs than nonobese individuals, because water needs depend upon metabolic rate, body surface area, and body weight.[24] Water turnover rates increase with BMI based on higher energy requirements, greater food consumption, and higher metabolic production.[24,25] The current guidelines for water intake according to the Institute of Medicine adequate intake standards (3.7 L/d for adult men and 2.7 L/d for adult women) are calculated independently of obesity status.[25] In contrast, several methods of estimating fluid needs used in clinical settings are weight dependent, with estimated water requirements of healthy community-dwelling individuals to be between 40 and 50 mL/kg a day.[26] Using this estimate, the water requirements for a 5-foot, 10-inch man who weighs 160 pounds (healthy weight) and a 5-foot, 10-inch man weighing 210 pounds (obese) would differ by more than 1 L. Clinicians are likely not aware of this greater water requirement among those with higher BMIs and thus may not provide adequate counseling to meet this requirement.

Although inadequate intake of water among obese adults may explain the observed findings, differential consumption of food with high water content may also contribute to the relationship between inadequate hydration and elevated BMI. Foods high in water or dietary fiber typically have fewer calories per gram and are thus lower in calorie density, whereas foods higher in fat are generally higher in calorie density.[23] Although increasing fruits and vegetables is often recommended as part of a healthy weight management strategy and is not thought to be a stand-alone intervention for obesity,[27] obese individuals and those with higher BMIs and increased hydration requirements may benefit from more guidance related to achieving adequate hydration through food and fluids.

Our study has several notable strengths, including the analysis of a nationally representative sample and the use of objective laboratory values of hydration and anthropometric measurements. Our findings, however, should be considered in the context of specific limitations. First, these data are cross-sectional and cannot be used to infer causation. Second, though urine osmolality is regarded as an excellent measure of hydration, it is possible that the 1-time reading available in the NHANES does not represent individuals' usual level of hydration.[7] Studies have indicated, however, that this value is an adequate and accurate measure of hydration on a population level.[11,28,29] Third, findings from our nationally representative sample of adults aged 18 to 64 years may not generalize to other age-groups (children, seniors) or to individuals in non–community-dwelling settings. Finally, because hydration is influ-

enced by multiple factors, broad recommendations on methods to improve hydration may be difficult to make. This association between inadequate hydration and obesity, after controlling for confounding variables, has not previously been shown on a population level and suggests that water, an essential nutrient, may deserve greater focus in weight management research and clinical strategies.

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Key words: hydration; obesity; body mass index; water; National Health and Nutrition Examination Survey

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