Intake of Tapwater and Total Water by Pregnant and Lactating Women

ABSTRACT

Background. Despite theoretically higher requirements for water due to physiologic demands of pregnancy and lactation, little is known of actual ranges of intake in pregnant and lactating women.

Methods. Population-based estimates of total water and tapwater intake in women of reproductive age were derived using data from the 1977–78 USDA Nationwide Food Consumption Survey. Three-day average intakes were calculated for 188 pregnant women, 77 lactating women, and 6,201 non-pregnant, non-lactating control women.

Results. Total water intake (mean ± SD) was 1,940 ± 686 g/day (median 1,835) for control women, 2,076 ± 743 g/day (median 1,928) for pregnant women and 2,242 ± 658 g/day (median 2,164) for lactating women. Tapwater intake was 1,157 ± 635 g/day (median 1,065) for control women, 1,189 ± 699 g/day (median 1,063) for pregnant women, and 1,310 ± 591 g/day (median 1,330) for lactating women. Total water intake was equal to or greater than 3,000 g/day among 7 percent of control women, 11 percent of pregnant women, and 13 percent of lactating women. Tapwater intake was equal to or greater than 2,000 g/day among 10 percent of control women, 15 percent of pregnant women, and 8 percent of lactating women.

Conclusions. These results should be useful in estimating amounts of nutrients and toxic substances that women of reproductive age obtain through the water supply. (*Am J Public Health* 1991;81:328–334)

Abby G. Ershow, ScD, Linda M. Brown, MPH, and Kenneth P. Cantor, PhD

Introduction

Although weight gain during pregnancy and milk output during lactation cause a theoretical increase in the physiological requirement for water,[1] the actual range of water intake among pregnant and lactating women is not known.[2] The relative importance of water as a dietary source of nutrients such as calcium cannot be evaluated in the absence of intake data. Furthermore, secondary exposure of a fetus or nursing child to toxic substances in the water supply makes accurate data on quantities of water consumed by the mother particularly important in establishing criteria for setting allowances of contaminant levels. To make population-based estimates of quantities and sources of tapwater and total water ingested by pregnant and lactating women, we used data from a large national US Department of Agriculture (USDA) dietary survey,[3–5] which provided an opportunity to consider water intake from all sources including solid foods. For purposes of comparison, we have also estimated intakes for similarly aged non-pregnant, non-lactating women who participated in the same survey.

Methods

Survey Design

In 1977–78 the USDA conducted the Nationwide Food Consumption Survey (NFCS) to gather dietary information on individuals living in randomly sampled nonmilitary households in the contiguous 48 states.[3] The NFCS first sampled households and asked the head of household to complete a seven-day household food use and purchase record. Of the 20,812 households contacted, 14,930 (72 percent) agreed to participate in this activity. Ninety-four percent of the individuals sampled from the participating households completed an interview that included a 24-hour recall; they were then asked to keep a food diary for the next two days.[6]

Participating in the Individual Intake Survey were 30,770 persons.[3] Of these, 87 women stated that they were nursing a child aged two years or less, and 214 women stated that they were four or more months pregnant (women less than four months pregnant were classified by the USDA as not pregnant).[3,4] The pregnant and lactating women interviewed for the NFCS were 15–49 years of age; thus, for potential control subjects, we identified all female NFCS participants 15–49 years old who were neither pregnant nor lactating (n = 7,227).

Analytic Sample

Our data analysis was confined to those NFCS participants having complete and usable data on demographic variables of interest, self-reported weight and height, and all foods, beverages, and drinking water consumed for three consecutive days. Overall, 86 percent of interviewed participants,[7] including 188 pregnant women, 77 lactating women, and 6,201 non-pregnant, non-lactating control women, fit these criteria.

Address reprint requests to Abby G. Ershow, ScD, Nutritionist, Lipid Metabolism-Atherogenesis Branch, National Heart, Lung and Blood Institute, Bethesda, MD 20892. Ms. Brown is an Epidemiologist with the Biostatistics Branch, National Cancer Institute; Dr. Cantor is an Epidemiologist, Environmental Epidemiology Branch, NCI.

This paper, submitted to the Journal June 23, 1989, was revised and accepted for publication August 6, 1990.

To compensate for deletions, we developed a weighting factor ("NCI weighting factor") equal to the inverse of the retained (i.e., not deleted) proportion of participants in each age-sex-race-region-season stratum.[7] This NCI weighting factor was derived for the entire data set and applies to the pregnant and lactating participants as well; it did not reflect any assumptions regarding diet or water intake of non-respondents. The retained participants did not differ from the original sample with regard to the distribution of values for age, sex, race, region, season of interview, urbanization, and education of heads of household,[7] and for this reason we consider our analytic sample to be satisfactorily representative of all surveyed participants. All calculations incorporated the NCI weighting factor as well as a USDA weighting factor that reflected the interview completion rate in each sampling stratum.[3,4,7]

Definition of Terms

"Drinking water" refers to plain water consumed directly as a beverage, but does not include tapwater used to prepare foods and other beverages. "Tapwater" includes drinking water as well as tapwater added in final preparation of foods and tapwater-based beverages. "Total water" includes all water from tapwater and non-tapwater sources, including water contained in food.

Calculation of Tapwater and Total Water Intake

The methods, coding procedures, and specific assumptions used in calculating tapwater and total water intake from the 4,545 foods and beverages reported as consumed by NFCS study participants have been fully described elsewhere[7] and will be summarized here. For all food items listed on the surveyed individuals' dietary records,[5,8] an experienced nutritionist (author AGE) estimated the proportion of the total water content likely to derive from household tapwater added during preparation. Examples of this estimated tapwater proportion are: 100 percent (tea, coffee); 84 percent (reconstituted frozen fruit juices); 50 percent (most reconstituted canned soups); 0 percent (meats, fresh whole milk, fresh fruit, carbonated beverages). These tapwater proportion values were merged with data on the water content of foods[5,7] and on the quantities of foods (including soups) and beverages consumed,[4] providing an estimate of total water and tapwater intake from all foods and beverages. To these estimates we added the cups of drinking water consumed each day, yielding the quantities of total water and tapwater from each dietary source for each individual over three days.[7] The original USDA dietary data were recorded in common household units and converted to grams during data processing.[8] Our results are expressed in grams, in keeping with the format of the public use data tapes.[4]

Statistical Methods

All calculations and statistical procedures were conducted using the SAS software package,[9] and incorporated weighting factors (see above) reflecting the interview completion rate in each sample stratum and the deletion of participants with incomplete data.[7] Values represent three-day averages for each individual. All values reported in the text represent mean ± standard deviation. Values for the fraction of total water intake provided by tapwater (see Table 3, below) represent the mean proportion for individuals.[10] Values for the fraction of total water and tapwater intake provided by various dietary sources (see "Results," below) represent the population proportion.[10]

For the entire group of study subjects (n = 6,466), sources of between-individuals variation in daily total water and tapwater intake were examined using analysis of variance (ANOVA) for unbalanced designs (PROC GLM).[9] The model included main-effects terms for reproductive status, race, urban/rural residence, region, and season; and covariate terms for age, weight, height, and mean household educational level. Education of the heads of household was a surrogate measure for income, which many participants (21 percent) would not report. Comparisons of means were made using a multiple comparison test (LSMEANS PDIFF) based on the analysis-of-variance model, in which the significance of each contrast was determined after adjusting for all other main effects and covariates.[9]

Results

Characteristics of Participants

Demographic and physical characteristics of the study participants are shown in Table 1. The women were fairly evenly distributed among the northeastern, southern, midwestern and western regions of the country. Interviews took place during all four seasons of the year. Most of the women were white and lived in urban or suburban rather than rural areas. The lactating women were generally older than the pregnant women and tended to live in households with a higher level of education. Self-reported heights and weights of our study sample compared favorably with physical measurements of height and weight made on adult females participating in the second US National Health and Nutrition Examination Survey (NHANES II).[11]

Total Water Intake

Effect of Reproductive Status. Total water intake of study participants is shown in Table 2. Mean and median daily consumption of total water for all participants was approximately 2 liters (i.e., 2,000 g). The upper ranges of intake, however, were much higher. Seven percent of control women, 11 percent of pregnant women, and 13 percent of lactating women consumed 3 liters (3,000 g) or more total water per day. Three percent, 4 percent, and 3 percent of control, pregnant, and lactating women, respectively, had total daily water intakes equal to or exceeding 3.5 liters (3,500 g).

Reproductive status was significantly associated with total water intake ($p < .001$). Lactating women consumed the largest quantity (g/day) of total water ($p < .001$ compared with control mean), but the mean intake of pregnant women was also significantly elevated ($p < .05$ compared with control women). The total water intake of lactating women was considerably higher than that of pregnant women, but this difference was not statistically significant due to relatively small numbers of participants.

Lactating women also had the highest mean intake of total water when expressed in terms of body weight ($p < .01$ compared with both control and pregnant women). Total water intake per unit of body weight did not differ between pregnant and control women.

Of the 77 lactating women, 64 had infants who also were NFCS study subjects; no information was available regarding the other 13 infants. Total water intake of these 64 lactating mothers was not significantly correlated with either the age (mean = 5 mo) or weight (mean = 7 kg) of their infants.

Total water intake per unit of energy (i.e., g/kcal/day) did not vary as a function of reproductive status. This reflects the parallel increase of water and energy intake: control, pregnant, and lactating women consumed 1,592 ± 561, 1,719 ± 556, and 1,887 ± 626 kcal/day, respectively (mean ± SD).

TABLE 1—Characteristics of Study Participants

	Pregnant Women	Lactating Women	Non-pregnant Non-lactating Women (Controls)
Number of Observations	188	77	6201
Age (yr) (mean ± SD)	25.5 ± 5.6	27.1 ± 4.8	30.4 ± 10.0
Weight* (kg) (mean ± SD)	65.8 ± 10.6	61.9 ± 12.4	61.8 ± 13.0
Height* (cm) (mean ± SD)	164 ± 6	164 ± 6	163 ± 7
Race (%)†			
White	79.6	94.8	81.9
Black	14.5	4.2	13.7
Other	6.0	1.0	4.5
Education** (%)			
Less than high school	20.1	7.9	23.6
High school graduate	37.9	32.3	42.5
More than high school	41.4	59.8	33.4
Urbanization of residence (%)			
Rural	22.4	25.9	26.6
Urban/Suburban	77.6	74.1	73.4
Region of residence (%)			
Northeast	20.8	20.7	25.1
Midwest	29.4	35.6	25.7
South	26.4	13.7	30.3
West	23.3	30.0	18.8
Season interviewed (%)			
Spring	24.6	27.5	22.6
Summer	26.7	26.1	25.7
Autumn	23.1	18.8	26.6
Winter	25.6	27.6	25.1

*By self-report
†Percentages may not add to 100.0%.
**Refers to the female head of household, who usually was the study participant.

Effects of other factors. The effects of factors other than reproductive status on total water intake were also examined in the entire sample of 6,466 women. The most striking effects were due to regional variations in residence. Total water intakes were lowest in the northeast (mean ± SD 1,827 ± 819 g/day; n = 1,551), intermediate in the south (1,955 ± 844 g/day; n = 2,147) and midwest (1,972 ± 912 g/day; n = 1,666), and highest in the west (2,063 ± 1,096 g/day; n = 1,102). Regarding another aspect of residence, rural women consumed more total water than urban/suburban women (1,997 ± 866 g/day, n = 1,885 vs 1,931 ± 925 g/day, n = 4,581).

Effects of race on total water intake may have been due to variation in food and beverage preferences. The small number of non-White, non-Black women had higher total water intakes (2,017 ± 957 g/day, n = 241) than White women (1,953 ± 898 g/day, n = 5,379), who in turn had higher total water intakes than Black women (1,893 ± 960 g/day, n = 846). Seasonal variation in total water intake was due primarily to elevated intake during the summer (2,011 ± 1,006 g/day; n = 1,384). Intakes were very similar in the autumn (1,916 ± 930 g/day; n = 1,617), winter (1,938 ± 960 g/day; n = 1,523), and spring (1,926 ± 762 g/day; n = 1,942).

Tapwater Intake

Effect of reproductive status. Mean and median daily consumption of tapwater for all groups (Table 3) was approximately 1.1 liters (1,100 g). Two liters (2,000 g) or more of tapwater were consumed daily by 10 percent, 15 percent, and 8 percent of control, pregnant, and lactating women respectively. Four percent of control and pregnant women and 3 percent of lactating women ingested 2.5 liters (2,500 g) or more of tapwater daily. Similar to the situation for total water, lactating women had the highest mean daily tapwater consumption ($p < .01$ compared with control women). The difference in tapwater intake between lactating women and pregnant women was nearly as large, but not significant due to small numbers. Pregnant women consumed only slightly more tapwater than control women. When compared with control women, mean tapwater intake per unit of body weight (i.e., g/kg/day) was also significantly higher in lactating women ($p < .05$) but not in pregnant women. Pregnant women actually had a slightly lower intake of tapwater per kg body weight than control women, possibly reflecting weight gain in pregnancy or a shift to sources of fluid (such as milk) that contain relatively little tapwater.

Effects of other factors. Effects on tapwater intake of factors other than reproductive status were similar in direction to those for total water, but the magnitude of the effects was smaller. Region again was the strongest residential factor. Intake was highest in the south (1,228 ± 798) and west (1,208 ± 982) and intermediate in the midwest (1,166 ± 857), whereas women in the northeast consumed less tapwater (1,034 ± 743 g/day) than in all other regions. Rural women consumed more tapwater (1,237 ± 819 g/day) than urban/suburban women (1,132 ± 847 g/day). Tapwater intake of non-White, non-Black women (1,232 ± 815 g/day) was higher than that of either White women (1,159 ± 841) or Black women (1,143 ± 849 g/day). Seasonal intake, which varied only slightly, was highest in the summer (1,198 ± 918), followed by winter (1,165 ± 895), autumn (1,144 ± 861), and spring (1,130 ± 711).

Sources of Total Water and Tapwater

The contribution of various dietary sources to total water intake is shown in Table 4. The reader should note that the mass of the non-water fraction of the foods does not enter into the calculation. For example, pregnant women had a mean intake of total water from milk and milk drinks of 308 g/day (Table 4), but their mean intake of milk *per se* would be a slightly higher figure. The presence of zeros in the 50th percentile column indicates that at least half of the women in that particular group consumed essentially no legumes, nuts or seeds, fruit juice, tea, coffee, soft drinks, or alcoholic beverages over the three days of the study.

Considerable individual variation is demonstrated by the marked differences in intake between the mean, median, and 95th percentiles. For example, the average coffee and tea intake of our subjects was not especially high. Table 4 shows that mean intake for pregnant women was 132 g water/day in tea and 197 g water/day in coffee, whereas lactating women consumed, on average, 253 g water/day in tea and 205 g water/day in coffee (an 8-oz cup ≃ 240 g water). The even lower 50th percentile values indicate that many of the women did not consume any tea or coffee at all. Nevertheless, a small fraction of subjects, representing the top 5 percent of

TABLE 2—Total Water Intake of Women 15–49 Years Old

Reproductive Status*	Mean	Standard Deviation	Percentile Distribution 5	10	25	50	75	90	95
g/day									
Control	1940	686	995	1172	1467	1835	2305	2831	3186
Pregnant	2076	743	1085	1236	1553	1928	2444	3028	3475
Lactating	2242	658	1185	1434	1833	2164	2658	3169	3353
g/kg/day									
Control	32.3	12.3	15.8	18.5	23.8	30.5	38.7	48.4	55.4
Pregnant	32.1	11.8	16.4	17.8	22.8	30.5	40.4	48.9	53.5
Lactating	37.0	11.6	19.6	21.8	28.4	35.1	45.0	53.7	59.2
g/kcal/day									
Control	1.3	0.9	0.7	0.8	0.9	1.2	1.5	2.0	2.5
Pregnant	1.3	0.5	0.7	0.8	0.9	1.2	1.5	1.9	2.2
Lactating	1.3	0.4	0.7	0.8	1.0	1.2	1.5	1.8	2.1

*Number of observations: non-pregnant, non-lactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).

TABLE 3—Tapwater Intake of Women 15–49 Years Old

Reproductive Status*	Mean	Standard Deviation	Percentile Distribution 5	10	25	50	75	90	95
g/day									
Control	1157	635	310	453	709	1065	1503	1983	2310
Pregnant	1189	699	274	419	713	1063	1501	2191	2424
Lactating	1310	591	430	612	855	1330	1693	1945	2191
g/kg/day									
Control	19.1	10.8	5.2	7.5	11.7	17.3	24.4	33.1	39.1
Pregnant	18.3	10.4	4.9	5.9	10.7	16.4	23.8	34.5	39.6
Lactating	21.4	9.8	7.4	9.8	14.8	20.5	26.8	35.1	37.4
Fraction of daily total water intake (%)									
Control	57.2	18.0	24.6	32.2	45.9	59.0	70.7	79.0	83.2
Pregnant	54.1	18.2	21.2	27.9	42.9	54.8	67.6	76.6	83.2
Lactating	57.0	15.8	27.4	38.0	49.5	58.1	65.9	76.4	80.5

*Number of observations: non-pregnant, non-lactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).

intake (i.e., the 95th percentile), drank nearly one liter per day of caffeinated beverage.

Sources of tapwater are shown in Table 5. Nearly all the tapwater consumed was provided by a small number of dietary items: drinking water; coffee; tea; grain and grain products; and fruit juices. (Carbonated beverages, most alcoholic beverages, and many fresh foods do not contain tapwater in the first place.) In contrast, a larger range of foods and beverages served as substantial sources of total water (Table 4).

Reproductive status had little effect on the relative contribution (expressed as the population proportion[10]) of drinking water, beverages, and foods to intake of total water (Table 4). For control, pregnant, and lactating women, respectively, the contribution to total water intake was 30 percent, 34 percent, and 30 percent for drinking water; 46 percent, 43 percent, and 45 percent for other beverages; and 24 percent, 23 percent, and 25 percent for foods.

Sources of tapwater intake varied more with reproductive status (Table 5). Drinking water contributed a larger fraction of the tapwater intake of pregnant women (58 percent) than for either control women (50 percent) or lactating women (52 percent). Other beverages accounted for a population proportion of 34 percent, 43 percent, and 41 percent of the tapwater intake of pregnant, control, and lactating women, respectively. Only 7 percent of the tapwater intake of our study participants was contributed by solid foods.

Discussion

By providing population-based estimates of total water and tapwater intake by pregnant and lactating women, our study addresses a nearly complete lack of information on this topic. Recent national surveys of tapwater use in Great Britain[12] and Canada[13] did not present data for pregnant or lactating women. Studies conducted by the California State Department of Health on the relationship of pregnancy outcome and water exposure did not evaluate quantities of water consumed from all sources.[14] A clinical study of fluid intake during lactation was very thorough but was conducted in a single locale (Iowa) using 26 self-selected volunteers.[1,15]

Our estimates derive from a relatively large final analytic sample that included 188 pregnant women and 77 lactating women. NHANES II,[16] which also used a stratified random national sampling design, included even fewer pregnant (n = 122) and lactating (n = 41) women than the 1977–78 NFCS. Larger numbers of pregnant and lactating participants would be desirable but cannot

TABLE 4—Total Water (g/Day) Derived from Various Dietary Sources by Women Aged 15–49 Years*

Sources	Control Women			Pregnant Women			Lactating Women		
		Percentile			Percentile			Percentile	
	Mean†	50	95	Mean†	50	95	Mean†	50	95
Drinking water	583	480	1440	695	640	1760	677	560	1600
Milk and milk drinks	162	107	523	308	273	749	306	285	820
Other dairy products	23	8	93	24	9	93	36	27	113
Meats, poultry, fish, eggs	126	114	263	121	104	252	133	117	256
Legumes, nuts, and seeds	13	0	77	18	0	88	15	0	72
Grains and grain products	90	65	257	98	69	246	119	82	387
Citrus and non-citrus fruit juices	57	0	234	69	0	280	64	0	219
Fruits, potatoes, vegetables, tomatoes	198	171	459	212	185	486	245	197	582
Fats, oils, dressings, sugars, sweets	9	3	41	9	3	40	10	6	50
Tea	148	0	630	132	0	617	253	77	848
Coffee and coffee substitutes	291	159	1045	197	0	955	205	80	955
Carbonated soft drinks**	174	110	590	130	73	464	117	57	440
Non-carbonated soft drinks**	38	0	222	48	0	257	38	0	222
Beer	17	0	110	7	0	0	17	0	147
Wine, spirits, liqueurs, mixed drinks	10	0	66	5	0	25	6	0	59
All Sources	1940	NA	NA	2076	NA	NA	2242	NA	NA

*Number of observations: nonpregnant, non-lactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).
†Individual means may not add to all-sources total due to rounding.
**Includes regular, low-calorie, and no-calorie soft drinks.
NA: Not appropriate to sum the columns for the 50th or 95th percentiles of intake.

TABLE 5—Tapwater (g/Day) Derived from Various Dietary Sources by Women Aged 15–49 Years*

Sources	Control Women			Pregnant Women			Lactating Women		
		Percentile			Percentile			Percentile	
	Mean†	50	95	Mean†	50	95	Mean†	50	95
Drinking water	583	480	1440	695	640	1760	677	560	1600
Milk and milk drinks	5	0	0	16	0	73	15	0	130
Other dairy products**	—	—	—	—	—	—	—	—	—
Meats, poultry, fish, eggs	15	0	70	12	0	65	15	0	70
Legumes, nuts, and seeds	8	0	45	11	0	54	8	0	54
Grains and grain products	42	20	164	46	21	170	61	35	240
Citrus and non-citrus fruit juices	26	0	138	34	0	161	39	0	153
Fruits, potatoes, vegetables, tomatoes	9	0	65	9	0	56	11	0	57
Fats, oils, dressings, sugars, sweets	4	0	33	4	0	24	3	0	37
Tea	148	0	630	132	0	617	253	77	848
Coffee and coffee substitutes	291	159	1045	197	0	955	205	80	955
Carbonated soft drinks**††	—	—	—	—	—	—	—	—	—
Non-carbonated soft drinks††	27	0	188	31	0	203	21	0	148
Beer**	—	—	—	—	—	—	—	—	—
Wine, spirits, liqueurs, mixed drinks	1	0	0	0	0	0	0	0	0
All Sources	1157	NA	NA	1189	NA	NA	1310	NA	NA

*Number of observations: non-pregnant, non-lactating controls (n = 6,201); pregnant (n = 188); lactating (n = 77).
†Individual means may not add to all-sources total due to rounding.
**Foods and beverages in this category are not sources of tap water.
††Includes regular, low-calorie, and no-calorie soft drinks.
NA: Not appropriate to sum the columns for the 50th or 95th percentiles of intake.

readily be obtained without expensive oversampling procedures.

We think it unlikely that our estimates of water intake are affected by serious non-response bias. The overall household response rate for the 1977–78 NFCS was 72 percent, very similar to the 73 percent individual response rate obtained for NHANES II,[11] and nearly all eligible individuals (94 percent) within participating NFCS households agreed to participate in the individual intake surveys as well. Furthermore, dietary data are probably no more susceptible to bias than other types of health information, and NHANES II investigators found no indication of household non-response bias for health-related variables.[11] In addition, there is no evidence that water intakes of persons with complete data differed systematically from intakes of persons lacking complete data. We thus consider our analytic sample to be representative of the surveyed study groups.

How reproducible (i.e., reliable) and accurate (i.e, valid) are our estimates? Few other data are available, but our estimates compared favorably with them. Median intake of at-home drinking water (plain tapwater) by pregnant women interviewed by the California Department of Health was 2–3 cups per day,[14] very similar to our finding that median drinking water intake of pregnant women was 640 g (2.7 cups) per day (Tables 4 and 5). The lactating women in our study had an average total water intake per unit of energy (1.3 g/kcal/day; Table 2) similar to that reported by lactating women in the Iowa study (1.4 g/kcal/day)[2] and in both studies two-thirds of the participants consumed more than the recommended 1 g/kcal.[1] As expected, our larger national sample of lactating women had a wider range of total water intake values (1,087–4,159 g/day), which completely encompassed the range for the 26 Iowa participants (1,920–3,957 g/day).[2] Both our study and the Iowa study found the highest level of total water intake to be approximately 4 liters (4,000 g) per day.

The non-pregnant, non-lactating control women in our study had a mean intake of total water from beverages (1,480 g/day; Table 4) very similar to that of adult British women (1.5–1.6 L/day).[12] Intake of tapwater from beverages (1,081 g/day; Table 5) also was very similar to that of British women (1.0–1.1 L/day).[12] Canadian women, on the other hand, consumed relatively more tapwater-based beverages (1.3–1.6 L/day).[13]

As the comparisons above indicate, our results are generally compatible with other published data despite differences in study population, intake methodology, and sample size. It is possible, however, that our estimates are on the low side. Using three days' worth of data for each participant would presumably allow the under-reporting biases of 24-hour recalls and the over-reporting biases of dietary records to balance out.[6,17] Nevertheless, energy intakes reported by NFCS participants were lower than expected and were very similar to the energy intakes yielded by the single 24-hour recall used in the NHANES II survey.[18] Under-reporting of food intake thus may account for the lower mean total water intake of our lactating study subjects (2,242 g/day, Table 2) compared with that of the Iowa participants (2,860 g/day).[2] Alternatively, the diets of the highly educated Iowa participants may not have been representative of lactating women's diets in general. The Iowa participants were studied as part of an attempt to increase milk production by deliberately increasing fluid intake,[15] and they may have been consuming extra fluid even during the baseline phase of the study.

How timely are the estimates? The data used for this analysis were collected in 1977–78. In the last decade there have been important changes in certain aspects of the food supply, including increased purchase and consumption of meals outside the home and greater intake of carbonated soft drinks.[19] Unfortunately, the USDA's more recent Continuing Survey of Food Intake by Individuals[19] did not collect information on intake of plain water (i.e., drinking water), and data from these surveys therefore cannot be used to derive either tapwater or total water intake.

Our population-based cross-sectional study confirms that pregnancy and lactation are associated with significant increases in water intake, although a prospective study design is needed to evaluate whether water intake increases spontaneously with the onset of pregnancy and lactation. The estimated theoretical increase in water requirement caused by lactation is 0.5–1.0 L/day[1,20] but in our study the mean daily total water intake of lactating women was only 302 g (i.e., 302 ml) higher than the total water intake of control women (Table 2). The non-pregnant, non-lactating control women in our study consumed quantities of total water well above the minimum amount needed to prevent dehydration. This implies that many if not most women may not need to increase their water intake when they become pregnant or begin to lactate, because their pre-pregnancy intakes were already more than adequate. Unnecessary recommendations to consume "lots of fluids" might inspire some women to replace nutritionally valuable solid foods with water or other nutrient-free beverages such as tea, coffee, or diet soda. Dietary counseling might be better directed towards the few women who habitually consume very small amounts of liquid.

Our evaluation of the relative contribution of various dietary sources to total water and tapwater intake has implications for questionnaire design. Studies of water consumption can be conducted more efficiently by limiting questions to the most important sources. We found that drinking water, coffee, and tea alone accounted for a population proportion[10] of 87 percent of tapwater intake by our study participants (calculated as the sum of source-specific means divided by the all-sources mean, Table 5). Adding reconstituted fruit juices and cooked grain products (such as rice, hot cereal, noodles, pasta) to this list brings this figure to 94 percent. A nearly complete assessment of the quantities of tapwater consumed could thus be made using a relatively short questionnaire. A longer list of sources (Table 4) would be needed to assess total water intake by questionnaire.

We found that women living in rural areas and in the western or southern regions of the United States consumed more total water and tapwater than women living in urban/suburban areas in the northeast and midwest. This could reflect differences in climatic temperature and humidity, physical activity, and diet, particularly beverages. Estimates of intake of water-borne elements might be improved by taking these residential factors into account. Season, on the other hand, was responsible for less variation, probably due to climate control and alternation throughout the year of hot and cold drinks. Similar minor effects of season were observed in Canada, where tapwater intake was slightly (5–10 percent) higher in the winter.[13] The Iowa study[2,15] also found that total water intake by lactating women was minimally affected by season.

Our findings may be used to estimate intake of minerals via tapwater. Calcium is of particular interest because of the very high demands imposed by reproduction; the Recommended Dietary Allowance (RDA) for calcium for most adult women is 800 mg/day, whereas for pregnant and lactating women the RDA is 1,200 mg/day.[1] The calcium content of home water supplies averages 50–60 mg/L, although in hard water areas the concentration may reach 145 mg/liter.[21] In the typical situation, pregnant or lactating women ingesting 1.2–1.3 liters/day of tapwater (Table 3) from the home supply would take in by this route only 60–80 mg/day of calcium, or about 5 percent of the 1,200 mg recommended daily allowance. Only the women living in areas with very hard water (145 mg/L) and drinking unusually large quantities of this hard water (2.2–2.4 L/day; 95th percentile of intake; Table 3) would obtain an appreciable amount of calcium from the tap.

Estimates of exposure to toxic metals and chemicals in tapwater often are made with the assumption that few persons consume more than 2 liters per day[21–24]. Canadian researchers found that 12 percent of adults consumed 2 liters or more of tapwater daily.[13] In our study 10 percent of

the non-pregnant, non-lactating women, 8 percent of the lactating women, and 15 percent of the pregnant women consumed 2,000 g/day or more of tap water (see "Results"), and 3–4 percent consumed 2,500 g or more. This suggests that 2 liters/day might not be a sufficiently high estimate of intake to protect 95 percent of these susceptible population groups, particularly pregnant women, from water-borne toxic substances unless a sufficient margin of safety is incorporated into estimates of exposure. □

Acknowledgments

The authors thank Karen Malley and Madeleine Kennedy for their excellent computer programming work and Fay Ryan for her expert assistance in preparing the manuscript.

References

1. Food and Nutrition Board, National Research Council: Recommended Dietary Allowances. Tenth edition. Washington, DC: National Academy of Sciences, 1989.
2. Stumbo PJ, Booth BM, Eichenberger JM, Dusdieker LB: Water intakes of lactating women. Am J Clin Nutr 1985;42:870–876.
3. US Department of Agriculture: Nutrient Intakes: Individuals in 48 States, Year 1977–78. Nationwide Food Consumption Survey 1977–78 Report I-2. Hyattsville, MD: Consumer Nutrition Division, Human Nutrition Information Service, 1984.
4. U.S. Department of Agriculture Nationwide Food Consumption Survey 1977–78 Individual Intake Data. Spring, Summer, Fall and Winter Basic Individual Food Intake Surveys. NTIS Accession No. PB80-190218/HBF, PB80-197429/HBF, PB80-200223/HBF, and PB81-118853/HBF. Springfield, VA: National Technical Information Service, US Department of Commerce.
5. US Department of Agriculture: USDA Nutrient Database for Individual Food Intake Surveys. Release 1. 1980 PB82-138504/ITBF. Springfield, VA: National Technical Information Service.
6. US Department of Health and Human Services, US Department of Agriculture: Nutrition Monitoring in the United States. DHHS Pub. No. (PHS)86-1255:237–247, Hyattsville, MD: National Center for Health Statistics, 1986.
7. Ershow AG, Cantor KP: Total Water and Tapwater Intake in the United States: Population-Based Estimates of Quantities and Sources. Life Sciences Research Office Monograph. Bethesda, MD: Federation of American Societies for Experimental Biology, 1989. Available from 9650 Rockville Pike, Bethesda, MD 20814.
8. US Department of Agriculture: Manual of Food Codes and Conversions of Measures to Gram-Weight for Use in Individual Food Intake Data from 1977–78. Nationwide Food Consumption Survey. Consumer and Food Economics Administrative Report No. 352. Hyattsville, MD: Human Nutrition Information Service, 1979.
9. SAS Institute: Statistical Analysis System. Fifth edition. Cary, NC: SAS Institute, Inc., 1985.
10. Krebs-Smith SM, Kott PS, Guenther PM: Mean proportion and population proportion: two answers to the same question? J Am Diet Assoc 1989;89:671–676.
11. US Department of Health and Human Services: Anthropometric reference data and prevalence of overweight. United States 1976–80. Series II, No. 238. Hyattsville, MD: National Center for Health Statistics, 1987.
12. Hopkin SM, Ellis JC: Drinking Water Consumption in Great Britain: A Survey of Drinking Habits with Special Reference to Tap-Water-Based Beverages. Technical Report TR-137. Medmenham, Eng: Water Research Centre, Medmenham Laboratory, 1980. Available from PO Box 16, Medmenham, Marlow, Bucks SL7-2HD England.
13. Environmental Health Directorate, Health Protection Branch, Department of National Health and Welfare: Tap Water Consumption in Canada. Report 82-EHD-80, Cat. No. H46-2/82-80E. Ottawa: Public Affairs Directorate, Department of National Health and Welfare, 1981. Available from Brooke Claxton Building Ottawa K1A-OK9.
14. California Department of Health Services: Water Exposure and Pregnancy Outcomes. Epidemiological Studies and Surveillance Section, California Department of Health Services, 1988. Available from 2151 Berkeley Way, Berkeley, CA 94704.
15. Dusdieker LB, Booth BM, Stumbo PJ, Eichenberger JM: Effect of supplemental fluids on human milk production. J Ped 1985;106:207–211.
16. US Department of Health and Human Services: Public Use Data Tape Documentation. Health History Supplement, ages 12–74 years. Tape Number 5305. National Health and Nutrition Examination Survey, 1976–1980. Hyattsville, MD: National Center for Health Statistics, 1983.
17. Burk MC, Pao EM. Methodology for Large-Scale Surveys of Household and Individual Diets. Home Economics Research Report No. 40. Hyattsville, MD: Agricultural Research Service, US Department of Agriculture, 1976.
18. Swan P: Food consumption by individuals in the United States: two major surveys. Ann Rev Nutr 1983;3:413–432.
19. US Department of Agriculture. Nationwide Food Consumption Survey: Continuing Survey of Food Intakes by Individuals. Women 19–50 years and their children 1–5 years, 1 day. NFCS, CSFII Report 86–1, Hyattsville, MD: Nutrition Monitoring Division, Human Nutrition Information Service, 1987.
20. Worthington-Roberts BS, Vermeersch J, Williams SR. Nutrition in pregnancy and lactation, Second edition. St. Louis, MO: CV Mosby Co, 1981.
21. Board on Toxicology and Environmental Health Hazards, National Research Council: Approach to the study. *In:* Drinking Water and Health, Vol 1. Washington, DC: National Academy of Sciences, 1980.
22. Board on Toxicology and Environmental Health Hazards, National Research Council: Contribution of drinking water to mineral nutrition in humans. *In:* Drinking Water and Health, Vol 3. Washington, DC: National Academy of Sciences, 1980.
23. Levin R. Reducing Lead in Drinking Water: A Benefit Analysis. EPA Report 230-09-86-019, Washington, DC: Office of Policy, Planning and Evaluation, US Environmental Protection Agency, 1987.
24. Environmental Studies Board, National Research Council: Lead in the Human Environment. Washington, DC: National Academy of Sciences, 1980.