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Predictors of use and consumption of public drinking water among pregnant women

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Disinfection by-products (DBPs) in drinking water may be associated with adverse pregnancy outcomes. However, the results from previous epidemiological studies are not consistent, perhaps in part due to individual variation in water use and consumption. This study was performed to evaluate and describe demographic and behavioral characteristics as predictors of ingested water, showering, bathing, and swimming among pregnant women. Water use and consumption data were collected through telephone interviews with 2297 pregnant women from three geographical sites in the southern United States. The data were analyzed according to demographic, health, and behavioral variables expected to be predictors of water use and thus potential confounding factors relating water use to pregnancy outcome. The candidate predictors were evaluated using backward elimination in regression models. Demographic variables tended to be more strongly predictive of the use and consumption of water than health and behavior-related factors. Non-Hispanic white women drank 0.4 (95% confidence interval (CI) 0.2; 0.7) liters more cold tap water per day than Hispanic women and 0.3 (95% CI 0.1; 0.4) liters more than non-Hispanic black women. Non-Hispanic white women also reported drinking a higher proportion of filtered tap water, whereas Hispanic women replaced more of their tap water with bottled water. Lower socioeconomic groups reported spending a longer time showering and bathing, but were less likely to use swimming pools. The results of this study should help researchers to anticipate and better control for confounding and misclassification in studies of exposure to DBPs and pregnancy outcomes.
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Introduction

Chlorination of public drinking water is widely used as a disinfection method throughout the world, but the potential effects of the resulting by-products on public health are largely unknown. Exposure to disinfection by-products (DBPs) has been associated with an increased risk of bladder cancer (Villanueva et al., 2004), and, while there might also be an association with adverse reproductive outcomes, the nature of this potential effect remains unclear (Nieuwenhuijsen et al., 2000a; Graves et al., 2001; Bove et al., 2002). Many of the epidemiological studies have relied on approximate measures of DBP exposure, such as concentration in the study subject's municipal water source, potentially resulting in substantial exposure misclassification.

Although considerable research has been conducted on individual contributors to exposure, including ingestion (Ershow et al., 1991; Shimokura et al., 1998), showering and bathing (Jo et al., 1990; Weisel and Jo 1996; Xu and Weisel 2005a, b), and swimming in chlorinated water (Aggazzotti et al., 1990), few studies have addressed the personal characteristics or behaviors that are related to these activities. In a Canadian study, King et al. (2004) evaluated individual water-use behavior from ingestion, showering, and bathing in relation to the total exposure to trihalomethanes and Kaur et al. (2004) studied tap-water-related activities in the UK. Zender et al. (2001) compared the water use between pregnant and non-pregnant women in a low socioeconomic population in the United States. Other studies have assessed the validity of questionnaires and examined patterns of use over time, expecting a change in the individual's usage, concluding that a larger part of the variability is found between subjects rather than within

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subjects (Shimokura et al., 1998; Barbone et al., 2002). The previous studies consistently reported considerable interindividual variation in exposure, raising concern that failure to account for such differences in epidemiologic studies could bias the results. This study was performed to evaluate which individual demographic and behavioral characteristics might be important predictors of water use and consumption in a large sample of pregnant women in the United States.

Methods

The participants were women enrolled between December 2000 and May 2004 as part of a large epidemiologic study of DBPs and pregnancy health (Promislow et al., 2004). Female residents from three geographic regions, served by three different public drinking water utilities in the United States, herein referred to as Sites 1, 2, and 3, were eligible for the study if they were at least 18 years of age, $\leqslant 12$ weeks pregnant, did not have any fertility treatment for the study pregnancy, and intended to deliver in the study area. A considerable effort was put into the recruitment process to ensure rapid enrollment of the large cohort of women in early pregnancy with a broad demographic range. Women were recruited from both private and public prenatal care sites and directly from the community through targeted mailings and posters in public places, as described in more detail elsewhere (Promislow et al., 2004).

Data collection included a telephone interview before 16 completed weeks of gestation and an ultrasound that was completed by 14 weeks' of gestation. Conception was dated by self-reported last menstrual period (LMP) or ultrasound. The interview was performed by trained interviewers and included detailed questions about the pregnancy, maternal health, demographic information, behavioral characteristics, and the use and consumption of tap and bottled water.

Predictor variables

The use and consumption of water was investigated in relation to a number of potential predictors, grouped into demographic, health, and behavioral characteristics. Season refers to the time of year of the interview, in which winter comprised December, January, and February, spring the three following months, etc. Maternal health characteristics included body mass index (BMI = weight/height^2), diabetes, pregnancy history, and nausea during pregnancy. BMI was based on self-reported prepregnancy weight and height, and categorized according to the Institute of Medicine's (1990) guidelines: low $\leqslant 19.8$, normal 19.8–26.0, overweight 26.1–29.0, and obese >29.0. Pregnancy history was classified as no prior pregnancy (including live birth, stillbirth, spontaneous abortion (SAB), induced abortion, ectopic, tubal, and molar), one or more prior pregnancies with no SAB, and one or more prior pregnancies ending in SAB. Behavioral variables included recreational exercise, smoking, and intake of caffeine, vitamins, alcohol, and illicit drugs. Caffeine intake included all types of beverages such as coffee, tea, and soda, and was categorized using the cut points 150 and 300 mg/day as was used by Fenster et al. (1997).

Water variables

The water variables investigated in this study included ingestion of filtered and unfiltered tap water (including beverages prepared with tap water), bottled water, showering and bathing habits, and the use of swimming pools, hot tubs, and Jacuzzis. Daily ingested amount was estimated based on cup sizes defined in the interview. Bottled water ingestion was calculated as the average amount based on reported bottled water container sizes. Among the women working outside the study area (about 8%), the question about ingested amount of tap water was asked separately for consumption at home and at work. This resulted in a higher average total amount for this group (about 15% higher) and we therefore deflated the totals by a set amount for women, who reported separately to make their mean values equal to those women who reported the aggregated amount. The total amount of drinking water was divided into unfiltered tap, filtered tap, and bottled water, and the mean proportions from each source were calculated. Use of filtered tap water was derived from a question on how much drinking water was filtered: none, little, some, most or all, assumed to be 0%, 20%, 40%, 75%, and 100%, respectively.

Data on bathing and showering habits were based on the self-reported number of minutes the women spent on average bathing and showering per week. Swimming was examined both as a dichotomous variable based on ever using a pool (yes/no) and by minutes per week spent in the pool among those who swam on average at least once a week. For this study, all data were included as reported, except for pool-use data for four women who reported implausibly long swimming times (more than 6 h/day).

Statistical methods

We calculated the mean and standard deviation of ingested cold tap water (liters per day), hot tap water, bottled water, the proportions of total cold water ingested as unfiltered tap, filtered tap and bottled water, minutes spent in showers and baths, use of pool (yes/no), and minutes spent in pool. To identify and select predictors of water use, we performed regression analysis for each water outcome variable, using backward elimination with a cut point of $P<0.10$ for variable inclusion in the final model. Because the outcomes of interest could be continuous, binary, or counts, three types of regression models were used as appropriate for each data type. Linear regression models were used for the ingested amount, showering, bathing, and time spent in pool and logistic regression models were used for the pool-use data (yes/no). The proportions of ingested amount were analyzed using a Poisson regression model in which the amount for each of unfiltered tap, cold filtered tap, and bottled water constituted the count, and the logarithm of the total was used as a regression variable with a constant coefficient of 1 for each observation (an offset). Because this required an integer count of the response variable and the number of liters per day provided too little variation, the amount was rescaled to deciliters for these models. The categories of the predictors were included as dummy variables and the reference category was determined by the largest number of observations. All analyses were performed using SAS 8.2 (SAS Institute, Inc., Cary, NC, USA).

Results

The total number of women included in this study was 2297, among whom the mean age at LMP was 27 years. The majority were non-Hispanic white, highly educated, married, and employed at the time of the interview.

Ingested water

The overall mean for ingested tap water was 1.7 L/day (percentiles: 25th = 0.5 L, 50th = 1.4 L, 75th = 2.4 L, and 90th = 3.8 L) and for bottled water 0.6 L/day (percentiles: 25th = 0.1 L, 50th = 0.2 L, 75th = 0.6 L, and 90th = 1.8 L). There was a lower amount of daily ingested cold tap water among women with low age and low education, and higher intake among married and non-Hispanic white women as well as those who were obese, used vitamins, and exercised (Table 1). In the adjusted model, women who were obese drank an average 0.3 L/day more than normal weight women, and those who used vitamins and exercised drank 0.3 and 0.2 L more than others, respectively. Of the demographic variables, study site, season, race/ethnicity, and income met the criterion for inclusion into the regression model for cold tap water. The predictors in the model showing notably large influence were site and race/ethnicity. Women in Site 1 reported drinking 0.5 L per day less cold tap water than women in Site 3, and non-Hispanic white women drank 0.4 L more per day compared to Hispanic women and 0.3 L more than non-Hispanic black women. These predictors showed the opposite pattern in the regression model for bottled water.

In the regression model for the proportion of cold tap water consumed as filtered water (Table 2), the intake was increased for older ages, higher income and education, and among unemployed. There was also an increased proportion of filtered water by more healthy behavior in terms of intake of vitamins and lack of drug, alcohol, or cigarette use. The proportion of bottled water was particularly high among Hispanic women (54%), whereas black, non-Hispanic women drank more (60%) of their water as unfiltered tap water. The overall mean of hot water intake was 0.2 L/day (95% CI 0.1, 0.2), which was too small for meaningful stratified analysis (data not shown).

Bath and shower

Average minutes spent in shower (Table 3) was 120 min/week (percentiles: 25th = 70 min, 50th = 105 min, 75th = 140 min, and 90th = 210 min). In the adjusted regression model (Table 4), increased time in the shower was associated with lower socioeconomic status (low age, low education, black or Hispanic ethnicity, and unmarried). There was also an increase in minutes spent in the shower among those with less healthy behavior in almost all the behavioral variables (Table 3), but only use of drugs met the criterion for inclusion in the regression model (Table 4). Those who reported use of drugs during pregnancy also reported showering about half an hour longer per week. For bathing, the average time was 50 min/week, with a somewhat skewed distribution as the results were based on the entire study population including those with no reported time in bath (percentiles: 25th = 0 min, 50th = 0 min, 75th = 60 min, and 90th = 140 min). In the subset of 727 women that reported taking baths, the average time was 138 min/week. Although the distribution for time bathing was skewed for the total population, a linear regression model was used, as no transformation or alternative model provided a better fit. The results from the regression model (Table 4) showed an increase with lower education, and an increase among black, unmarried, and smoking women.

Use of pool and Jacuzzi/hot tub

The overall proportion of women reporting swimming in pools was 31% (Table 3). For all the demographic variables, the pool use varied to some extent and most of them were also included in the logistic regression model but the relationship was opposite of that for time spent bathing and showering. The odds ratio for any swimming was elevated among those who were non-Hispanic white, highly educated, employed, and in the upper income category (results not shown). Among the health variables, the odds ratios were increased for women with gestational diabetes and previously pregnant women without SAB. Pool use was also more frequent among women taking vitamins and non-smokers, but among the behavioral variables only recreational exercise and use of drugs remained in the logistic regression model.

The results for time spent in the pool (Table 3) were based only on women who used the pool regularly, on average at least once per week. In general, the time did not deviate much from the overall average of 2.6 h/week for any of the predictors. Longer time in the pool was associated with less healthy behavior but the small numbers prevented meaningful regression analysis. Of the 11% of women reporting use of Jacuzzi or hot tub, only 4% were able to provide an estimated time for their use (data not shown). The limited

Table 1. Mean and standard deviation for unadjusted daily intake of cold tap water and bottled drinking water (liters per day) and estimates and 95% CI for predictive regression models.

	Cold tap water			Bottled water		
	Daily ingestion		Regression model	Daily ingestion		Regression model
Variables	No.	Mean (SD)	Estimate[a] (95% CI)	No.	Mean (SD)	Estimate[a] (95% CI)
Demographics						
Home	2293	1.3 (1.2)				
Work	2295	0.4 (0.6)				
Total	2293	1.7 (1.4)		2284	0.6 (0.9)	
Intercept			2.0 (1.8, 2.1)			0.6 (0.5, 0.8)
Geographic region						
Site 1	1019	1.8 (1.4)	Reference	1016	0.5 (0.9)	Reference
Site 2	864	1.9 (1.4)	0.1 (−0.0, 0.2)	862	0.4 (0.7)	−0.2 (−0.3, −0.1)
Site 3	410	1.1 (1.3)	−0.5 (−0.7, −0.3)	406	1.1 (1.2)	0.5 (0.4, 0.6)
Season						
Winter	587	1.6 (1.3)	−0.1 (−0.3, 0.1)	584	0.6 (1.0)	
Spring	622	1.7 (1.4)	0.1 (−0.0, 0.3)	622	0.6 (1.0)	
Summer	566	1.8 (1.6)	Reference	560	0.6 (0.9)	
Fall	518	1.8 (1.5)	0.1 (−0.1, 0.2)	518	0.5 (0.9)	
Age at LMP						
17–25	852	1.6 (1.4)		848	0.6 (1.0)	
26–30	714	1.8 (1.5)		710	0.6 (1.0)	
31–35	539	1.7 (1.3)		538	0.5 (0.8)	
⩾36	188	1.8 (1.4)		188	0.5 (0.9)	
Education						
⩽High school	691	1.5 (1.5)		687	0.6 (1.0)	
Some college	498	1.7 (1.5)		496	0.6 (1.0)	
⩾4-year college	1103	1.8 (1.3)		1100	0.5 (0.9)	
Race/ethnicity						
White, non hispanic	1276	1.8 (1.4)	Reference	1273	0.5 (0.9)	Reference
Black, non hispanic	727	1.6 (1.5)	−0.3 (−0.4, −0.1)	722	0.6 (0.9)	0.1 (0.0, 0.2)
Hispanic, any race	204	1.1 (1.3)	−0.4 (−0.7, −0.2)	202	1.1 (1.2)	0.2 (0.1, 0.4)
Other	84	1.9 (1.5)	0.0 (−0.4, 0.3)	85	0.5 (0.9)	0.0 (−0.2, 0.2)
Martial status						
Single, never married	719	1.6 (1.5)		713	0.6 (1.0)	
Married	1497	1.8 (1.4)		1494	0.5 (0.9)	
Other	76	1.7 (1.9)		76	0.6 (0.9)	
Annual income ($)						
⩽40,000	967	1.6 (1.5)	Reference	962	0.6 (1.0)	
40,001–80,000	730	1.8 (1.4)	0.0 (−0.1, 0.2)	730	0.5 (0.9)	
>80,000	501	1.7 (1.3)	−0.2 (−0.4, −0.0)	499	0.5 (0.9)	
Employment						
No	681	1.7 (1.5)		679	0.5 (0.9)	
Yes	1611	1.7 (1.4)		1604	0.6 (0.9)	
Health						
BMI[b]						
Low	268	1.6 (1.3)	0.0 (−0.2, 0.2)	267	0.6 (1.0)	
Normal	1128	1.7 (1.4)	Reference	1123	0.5 (0.9)	
Overweight	288	1.7 (1.5)	0.1 (−0.1, 0.2)	288	0.6 (0.9)	
Obese	542	1.8 (1.6)	0.3 (0.1, 0.4)	540	0.6 (1.0)	

Table 1. *Continued*

	Cold tap water			Bottled water		
	Daily ingestion		Regression model	Daily ingestion		Regression model
Variables	No.	Mean (SD)	Estimate[a] (95% CI)	No.	Mean (SD)	Estimate[a] (95% CI)
Diabetes						
No diabetes	2221	1.7 (1.4)	Reference	2213	0.6 (0.9)	
Regular diabetes	17	2.6 (2.1)	0.9 (0.2, 1.5)	17	0.4 (0.8)	
Gestational diabetes	55	1.6 (1.6)	−0.1 (−0.5, 0.3)	54	0.6 (0.9)	
Nausea during pregnacy						
No	387	1.6 (1.4)		385	0.6 (1.0)	
Yes	1904	1.7 (1.4)		1897	0.6 (0.9)	
Pregnancy history						
No prior pregnancy	691	1.7 (1.4)		685	0.6 (1.0)	0.1 (0.1, 0.2)
Prior pregnancy with no SAB	1064	1.7 (1.4)		1063	0.5 (0.9)	Reference
Prior pregnancy with SAB	538	1.8 (1.5)		536	0.6 (1.0)	0.1 (−0.0, 0.2)
Behavior						
Caffeine						
0 mg/day	578	1.8 (1.5)		577	0.6 (1.0)	
1–150 mg/day	522	1.6 (1.3)		522	0.5 (0.8)	
151–300 mg/day	433	1.6 (1.4)		433	0.6 (0.9)	
>300 mg/day	760	1.7 (1.5)		752	0.6 (1.0)	
Vitamin use						
No	180	1.4 (1.4)	−0.3 (−0.5, −0.1)	176	0.5 (0.8)	
Yes	2113	1.7 (1.4)	Reference	2108	0.6 (0.9)	
Smoking						
Nonsmoker	2164	1.7 (1.4)		2155	0.6 (0.9)	Reference
<10 cigarettes/day	84	1.8 (1.5)		84	0.8 (1.3)	0.4 (0.1, 0.6)
⩾10 cigarettes/day	45	1.8 (1.6)		45	0.4 (0.7)	−0.2 (−0.3, −0.0)
Alcohol use						
No	2257	1.7 (1.4)		2247	0.6 (0.9)	
Yes	36	1.6 (1.2)		37	0.5 (0.8)	
Recreational exercise						
No	1061	1.5 (1.4)	−0.2 (−0.4, −0, 1)	1054	0.6 (0.9)	−0.1 (−0.1, 0.0)
Yes	1232	1.8 (1.4)	Reference	1230	0.6 (1.0)	Reference
Illicit drug use						
No	2024	1.7 (1.4)		2017	0.6 (0.9)	
Yes	268	1.7 (1.5)		266	0.6 (1.0)	

Abbreviations: BMI, body mass index; CI, confidence interval; LMP, last menstrual period; SAB, spontaneous abortion; SD, standard deviation.
[a]Adjusted for all other variables that were not excluded in the backward elimination process.
[b]BMI cut points: low, <19.8, normal, 19.8–26.0, overweight, 26.1–29.0, and obese >29.0.

number of women with regular hot tub or Jacuzzi use precluded further analyses.

Discussion

In this study, we evaluated demographic and behavioral characteristics as predictors of ingested water, shower, bathing, and swimming among a large number of pregnant women in the United States. We found that healthier behavior was associated with increased tap water ingestion, higher proportion of filtered water, fewer minutes in shower and bath, and increased pool use. Following adjustment for all other variables in the regression models, we found that the demographic variables were more strongly predictive than the

Table 2. Means, standard deviations, rate ratios and 95% CI, for the proportion of ingested water consumed as unfiltered tap water, filtered tap water, and bottled water.

		Cold unfiltered tap		Cold filtered tap		Bottled water	
Variables	No.	Mean (%)	Rate ratio[a] (95% CI)	Mean (%)	Rate ratio[a] (95% CI)	Mean (%)	Rate ratio[a] (95% CI)
TOTAL	2280	52		19		28	
Demographics							
Geographic region							
Site 1	1014	46	Reference	28	Reference	26	Reference
Site 2	860	67	1.4 (1.4, 1.5)	13	0.6 (0.6, 0.6)	19	0.7 (0.7, 0.7)
Site 3	406	37	0.8 (0.7, 0.8)	10	0.6 (0.6, 0.6)	53	2.0 (1.9, 2.1)
Season							
Winter	583	52		19	0.9 (0.8, 0.9)	29	1.1 (1.0, 1.1)
Spring	621	53		19	Reference	28	Reference
Summer	559	50		20	1.0 (0.9, 1.0)	29	1.0 (1.0, 1.1)
Fall	517	54		19	1.0 (0.9, 1.0)	26	1.0 (1.0, 1.1)
Age at LMP							
⩽25	845	55	Reference	11	Reference	33	Reference
26–30	709	49	1.0 (0.9, 1.0)	22	1.2 (1.1, 1.3)	28	0.9 (0.9, 1.0)
31–35	538	51	1.0 (0.9, 1.0)	27	1.2 (1.1, 1.3)	22	0.9 (0.9, 1.0)
⩾36	188	53	1.0 (1.0, 1.1)	22	1.2 (1.1, 1.3)	25	0.9 (0.8, 1.0)
Education							
⩽High school	685	56	1.1 (1.0, 1.1)	8	0.8 (0.7, 0.8)	34	1.1 (1.0, 1.2)
Some college	495	53	1.0 (1.0, 1.0)	16	1.0 (0.9, 1.0)	30	1.1 (1.1, 1.2)
⩾4-year college	1099	49	Reference	27	Reference	23	Reference
Race/ethnicity							
White, non hispanic	1272	50	Reference	26	Reference	23	Reference
Black, non hispanic	720	60	1.1 (1.0, 1.1)	9	0.5 (0.5, 0.6)	30	1.4 (1.3, 1.4)
Hispanic, any race	202	37	0.9 (0.8, 0.9)	9	0.6 (0.5, 0.6)	54	1.5 (1.4, 1.6)
Other	84	48	1.0 (0.9, 1.0)	27	1.0 (0.9, 1.1)	25	1.1 (1.0, 1.3)
Marital status							
Single, never married	711	57		9	0.8 (0.7, 0.8)	33	1.1 (1.0, 1.1)
Married	1492	50		25	Reference	25	Reference
Other	76	57		9	0.7 (0.6, 0.8)	34	1.1 (1.0, 1.2)
Annual income ($)							
⩽40,000	960	56	Reference	11	Reference	33	Reference
40,001–80,000	728	51	0.9 (0.9, 0.9)	24	1.2 (1.1, 1.3)	24	1.1 (1.0, 1.1)
>80,000	499	45	0.8 (0.8, 0.8)	29	1.2 (1.1, 1.3)	25	1.4 (1.3, 1.5)
Employment							
No	678	52	0.9 (0.9, 1.0)	21	1.2 (1.1, 1.2)	27	0.9 (0.9, 1.0)
Yes	1601	52	Reference	19	Reference	29	Reference
Health							
BMI[b]							
Low	266	50	1.0 (0.9, 1.0)	21		29	1.1 (1.0, 1.2)
Normal	1121	51	Reference	22		27	Reference
Overweight	287	53	1.0 (0.9, 1.0)	18		28	1.0 (1.0, 1.1)
Obese	540	56	1.0 (1.0, 1.0)	14		29	1.0 (0.9, 1.0)
Diabetes							
No diabetes	2209	52	Reference	19		28	Reference
Regular diabetes	17	69	1.2 (1.0, 1.3)	15		16	0.6 (0.5, 0.8)
Gestational diabetes	54	50	1.0 (0.9, 1.0)	22		27	1.1 (1.0, 1.3)

Table 2. *Continued*

Variables	No.	Cold unfiltered tap		Cold filtered tap		Bottled water	
		Mean (%)	Rate ratio[a] (95% CI)	Mean (%)	Rate ratio[a] (95% CI)	Mean (%)	Rate ratio[a] (95% CI)
Nausea during pregnancy							
No	385	54		18		28	
Yes	1893	52		20		28	
Pregnancy history							
No prior pregnancy	685	48	0.9 (0.9, 1.0)	21		31	1.2 (1.1, 1.2)
Prior pregnancy with no SAB	1060	54	Reference	18		27	Reference
Prior pregnancy with SAB	535	53	1.0 (1.0, 1.0)	20		26	1.1 (1.0, 1.1)
Behavior							
Caffeine							
0 mg/day	577	50	0.9 (0.9, 1.0)	22	1.2 (1.1, 1.2)	27	1.0 (1.0, 1.0)
1–150 mg/day	520	53	1.0 (1.0, 1.1)	17	1.0 (1.0, 1.0)	29	1.0 (0.9, 1.0)
151–300 mg/day	432	52	1.1 (1.0, 1.1)	17	0.9 (0.9, 1.0)	30	0.9 (0.9, 1.0)
>300 mg/day	751	53	Reference	19	Reference	27	Reference
Vitamin use							
No	176	57		8	0.7 (0.7, 0.8)	34	
Yes	2104	52		20	Reference	28	
Smoking							
Nonsmoker	2151	51	Reference	20	Reference	28	Reference
<10 cigarettes/day	84	60	1.0 (0.9, 1.1)	10	0.8 (0.7, 0.9)	28	1.2 (1.1, 1.3)
⩾10 cigarettes/day	45	66	1.5 (1.4, 1.7)	7	0.5 (0.4, 0.7)	22	0.4 (0.4, 0.5)
Alcohol use							
No	2244	52	Reference	19	Reference	28	Reference
Yes	36	58	1.1 (1.0, 1.3)	19	0.5 (0.4, 0.6)	23	1.2 (1.0, 1.4)
Recreational exercise							
No	1053	54		14		31	
Yes	1227	51		24		26	
Illicit drug use							
No	2013	51	Reference	20	Reference	28	
Yes	266	56	1.1 (1.0, 1.1)	12	0.9 (0.8, 1.0)	31	

Abbreviations: BMI, body mass index; CI, confidence interval; LMP, last menstrual period; SAB, spontaneous abortion.
[a]Adjusted for all other variables that were not excluded in the backward elimination process.
[b]BMI cut points: low, <19.8, normal, 19.8–26.0, overweight, 26.1–29.0, and obese >29.0.

health and behavioral variables. Lower socioeconomic groups spent more time showering and bathing, but were less likely to use a pool. Ingestion of cold tap water was greater among non-Hispanic white women and women living in Site 3 and Site 2, and the use of water filters was associated with higher socioeconomic groups. Use of vitamins and abstinence from smoking, alcohol, or illicit drugs were also associated with use of filtered water, which is likely linked to sociodemographic differences but nevertheless reflected a pattern that could be of importance in epidemiologic studies.

Previous studies of patterns of tap water consumption and use have raised concern that the large variation found between subgroups of women could bias the results of epidemiological studies (Shimokura et al., 1998; Zender et al., 2001; Barbone et al., 2002; King et al., 2004). However, few previous studies have explored the associations between individual characteristics and water-related activities in detail. Earlier studies on water consumption performed in the UK found that differences between regions and socioeconomic classes were relatively small, in general about 10% (Nieuwenhuijsen et al., 2000b). In our study, there was nearly a 30% difference in ingested tap water amount between the regions ranging from 1.5 to 2.1 L/day in the adjusted model. This difference was, however, balanced by the amount of bottled water consumed, and the difference between the highest and the lowest region for the total amount of ingested water (tap and bottled together) was about 8%.

The total crude amount of cold ingested tap water (1.7 L/day) in our study was slightly less than what was found in a

Table 3. Means and standard deviations for proportion of pool use and weekly time spent showering, bathing, and swimming

	Shower		Bath		Swimming pool				
	Min/week		Min/week		Using pool			Time in pool (h/week)	
	No.	Mean (SD)	No.	Mean (SD)	Yes	No.	Prop. Users (%)	No.	Mean (SD)
TOTAL	2292	120 (117)	2013	50 (118)	721	1572	31	206	2.6 (3.7)
Demographics									
Geographic region									
Site 1	1021	113 (107)	877	27 (87)	406	612	40	126	2.2 (2.8)
Site 2	862	112 (106)	773	76 (138)	220	645	25	58	3.1 (5.2)
Site 3	409	158 (149)	363	50 (128)	95	315	23	22	3.6 (3.6)
Season									
Winter	588	123 (120)	524	46 (102)	92	496	16	10	1.5 (1.7)
Spring	620	115 (99)	549	49 (101)	68	555	11	21	1.6 (0.8)
Summer	567	127 (142)	487	63 (168)	306	257	54	138	2.5 (2.7)
Fall	517	117 (99)	453	40 (86)	255	264	49	37	3.6 (7.0)
Age at LMP									
⩽25	853	148 (146)	767	76 (147)	228	624	27	56	3.6 (5.2)
26–30	713	116 (113)	619	43 (117)	226	489	32	66	1.8 (2.0)
31–35	538	94 (66)	459	25 (60)	197	341	37	64	2.9 (4.0)
⩾36	188	86 (48)	168	24 (62)	70	118	37	20	1.1 (0.9)
Education									
⩽High school	691	162 (174)	630	95 (180)	155	536	22	39	3.2 (4.2)
Some college	497	126 (101)	435	48 (88)	141	358	28	42	3.6 (5.2)
⩾4-year college	1103	92 (53)	947	20 (50)	425	677	39	125	2.1 (2.9)
Race/ethnicity									
White, non hispanic	1277	96 (64)	1090	25 (69)	518	756	41	170	2.6 (3.8)
Black, non hispanic	724	150 (172)	660	105 (171)	133	595	18	23	2.2 (2.1)
Hispanic, any race	204	169 (102)	182	16 (45)	50	154	25	8	5.4 (6.4)
Other	85	115 (82)	79	19 (62)	19	66	22	5	1 (0.6)
Martial status									
Single, never married	717	162 (164)	647	98 (174)	185	534	26	45	4.2 (5.8)
Married	1498	98 (62)	1298	25 (60)	517	980	35	158	2.1 (2.8)
Other	76	167 (229)	67	73 (155)	19	57	25	3	2.7 (2.9)
Annual income ($)									
⩽40,000	967	145 (140)	866	73 (147)	249	719	26	59	3.1 (5.2)
40,001–80,000	730	103 (85)	637	28 (66)	235	495	32	68	2.3 (2.1)
>80,000	501	90 (45)	427	17 (39)	214	287	43	72	2.4 (3.6)
Employment									
No	682	125 (120)	617	56 (131)	234	447	34	82	2.6 (3.9)
Yes	1609	119 (115)	1395	47 (113)	487	1124	30	124	2.6 (3.7)
Health									
BMI[a]									
Low	269	121 (121)	237	44 (123)	92	175	34	19	2.1 (1.7)
Normal	1128	113 (116)	983	39 (92)	389	739	34	122	2.6 (4.0)
Over weight	287	119 (97)	261	55 (159)	100	189	35	23	2.7 (4.2)
Obese	541	136 (125)	471	66 (114)	123	419	23	34	2.3 (2.8)
Diabetes									
No diabetes	2220	120 (117)	1946	49 (118)	692	1529	31	196	2.6 (3.8)
Regular diabetes	17	139 (87)	15	49 (90)	3	14	18	1	3
Gestational diabetes	55	122 (95)	52	68 (149)	26	29	47	9	1.7 (1.1)

Table 3. *Continued*

	Shower		Bath		Swimming pool				
	Min/week		Min/week		Using pool			Time in pool (h/week)	
	No.	Mean (SD)	No.	Mean (SD)	Yes	No.	Prop. Users (%)	No.	Mean (SD)
Nausea during pregnancy									
No	387	118 (103)	341	47 (97)	123	264	32	40	3.4 (5.0)
Yes	1903	121 (119)	1670	50 (122)	597	1307	31	166	2.4 (3.4)
Pregnancy history									
No prior pregnancy	691	120 (111)	594	42 (93)	205	486	30	51	3.6 (5.6)
Prior pregnancy with no SAB	1063	122 (112)	946	56 (125)	345	719	32	108	2.5 (3.2)
Prior pregnancy with SAB	538	118 (132)	473	49 (133)	171	367	32	47	1.7 (1.5)
Behavior									
Caffeine									
0 mg/day	575	122 (128)	514	55 (151)	192	385	33	49	1.7 (1.4)
1–150 mg/day	523	119 (119)	467	46 (89)	132	391	25	27	2.6 (4.1)
151–300 mg/day	433	128 (133)	383	52 (112)	140	293	32	37	2.5 (2.3)
>300 mg/day	761	116 (94)	649	47 (112)	257	503	34	93	3.1 (4.8)
Vitamin use									
No	179	162 (191)	163	85 (143)	40	140	22	6	4 (2.5)
Yes	2113	117 (107)	1850	47 (116)	681	1432	32	200	2.5 (3.8)
Smoking									
Nonsmoker	2163	119 (115)	1896	47 (114)	684	1480	32	196	2.6 (3.8)
<10 cigarettes/day	84	130 (91)	74	82 (162)	26	58	31	7	3.1 (2.4)
⩾10 cigarettes/day	45	159 (201)	43	115 (196)	11	34	24	3	3.3 (2.5)
Alcohol use									
No	2255	120 (115)	1980	50 (118)	706	1550	31	198	2.6 (3.8)
Yes	37	126 (207)	33	60 (133)	15	22	41	8	2.9 (2.2)
Recreational exercise									
No	1059	132 (132)	952	59 (118)	261	801	25	49	3.2 (4.3)
Yes	1233	110 (100)	1061	42 (119)	460	771	37	157	2.4 (3.6)
Illicit drug use									
No	2023	120 (117)	1773	46 (106)	626	1399	31	184	2.5 (3.7)
Yes	268	127 (117)	239	81 (185)	95	172	36	22	3.7 (4.3)

Abbreviations: BMI, body mass index; LMP, last menstrual period; SAB, spontaneous abortion.
[a]BMI cutpoints: low, <19.8, normal, 19.8–26.0, overweight, 26.1–29.0, and obese >29.

previous study in the United States (Zender et al., 2001), but substantially more than an earlier US study (Shimokura et al., 1998) and more recent studies conducted in Europe (Barbone et al., 2002; Kaur et al., 2004) which all reported an average of 0.6 L/day of total ingestion. In a study of water use in Tucson, AZ in the United States, Williams et al (2001) found that Hispanics were more likely to drink bottled water and spend more time showering than non-Hispanics. This pattern was supported in our study, although the proportion of water ingested as unfiltered, filtered, or bottled water differed. In our study, the overall proportion of ingested unfiltered tap water was 52%, filtered tap water 19%, and bottled water 28%, whereas in the study by Williams et al. (2001), the corresponding proportions were 30%, 30%, and 37%. The Tucson study, however, included men (about 40% of the subjects) and a much larger number of Hispanics, which, along with regional differences, could partly explain the difference.

The average time spent showering was about 120 min/week in our study, which is in agreement with the previous American and Italian studies (Shimokura et al., 1998; Zender et al., 2001; Barbone et al., 2002), but was about 1 h more than found in the British study (Kaur et al., 2004), which reported an average of 54 min/week. The time spent in baths (50 min/week) was about the same, however, as in the British study. The other studies reported only the number of minutes for each bath with no information regarding frequency. Swimming in pools was less common among the

Table 4. Final regression model coefficients and 95% Cis for weekly time spent showering and bathing

	Shower	Bath
	Estimate[a] (95% CI)	Estimate[a] (95% CI)
Intercept	95 (82, 108)	−3 (−13, 8)
Demographics		
Geographic region		
Site 1	Reference	Reference
Site 2	−12 (−22, −2)	35 (24, 45)
Site 3	13 (−1, 28)	14 (−1, 30)
Age at LMP		
⩽25	Reference	
26–30	−2 (−15, 10)	
31–35	−12 (−26, 3)	
⩾36	−24 (−43, −5)	
Education		
⩽High school	30 (16, 44)	35 (21, 49)
Some college	12 (−1, 25)	3 (−10, 17)
⩾4-year college	Reference	Reference
Race/ethnicity		
White, non hispanic	Reference	Reference
Black, non hispanic	24 (12, 36)	50 (38, 63)
Hispanic, any race	35 (16, 54)	−28 (−48, −9)
Other	12 (−12, 36)	−6 (−31, 18)
Martial status		
Single, never married	37 (24, 51)	29 (16, 42)
Married	Reference	Reference
Other	52 (26, 78)	24 (−3, 52)
Behavior		
Caffeine		
0 mg/day	8 (−5, 21)	
1–150 mg/day	−12 (−25, 2)	
151–300 mg/day	1 (−13, 15)	
>300 mg/day	Reference	
Smoking		
Nonsmoker	Reference	
<10 cigarettes/day	16 (−10, 42)	
⩾10 cigarettes/day	52 (18, 86)	
Illicit drug use		
No	−29 (−44, −14)	
Yes	Reference	

Abbreviations: CI, confidence interval; LMP, last menstrual period.
[a]Adjusted for all other variables that were not excluded in the backward elimination process.

women in our study than in previous studies from the UK (Nieuwenhuijsen et al., 2002; Kaur et al., 2004) in which more than 50% of the women reported swimming in a pool compared to 30% in our study. However, among the women regularly swimming, the time they spent was on average longer (2.6 h/week) in our study compared to the UK study where the majority swam for less than an hour per week. Two previous US studies (Shimokura et al., 1998; Zender et al., 2001) reported less frequent use of a pool (25% and 8% of the study subjects, respectively), whereas in a study by Lynberg et al. (2001), also conducted in the United States, 58% of the participants reported use of a pool.

Our study has several strengths including collecting water information during, instead of after, the pregnancy, minimizing the risk for recall bias. Although the majority of the women were from higher socioeconomic groups, we had sufficient statistical power to evaluate subgroups owing to a large sample size and considerable variability in the water use and confounding variables. The comprehensive questionnaire used during the interviews provided detailed individual information on water use as well as demographic, health, and behavioral characteristics. The main limitation of the study is the inherent inaccuracy in self-reported data. We could not validate the information provided, and participating in the study might lead to more awareness and potentially cause over- or under-reporting or even change in actual behavior. Also, the fact that the study population was a non-random sample consisting of volunteers limits the generalizability of the findings. In order to assess to what extent the study participants differed from other women giving birth during the same period in the same area, vital records from the relevant state health departments were obtained. In both Site 1 and Site 2, the participants were similar to the total population with respect to age, but more highly educated, more likely to be non-Hispanic white, and more likely to be nulliparous. In Site 3, the participants were again similar with respect to age and education and more likely to be nulliparous, but more likely to be Hispanic than other pregnant women not taking part in the study. More details about this can be found in the Right From the Start Final Report (Savitz et al., 2005). Although the study is limited to three geographic areas, this is the largest and most diverse population sampled to date for an epidemiologic study of DBPs. Although they might not be representative of population level usage for the whole United States population, they are the most recent data available and likely best represent current trends in filtration and bottled water usage.

The differences in water use and consumption between subgroups found in our study highlight the potential for two types of bias in epidemiologic studies: misclassification and confounding. Failure to acknowledge differences in water use between individuals, or at least subgroups, might lead to misclassification of the exposure, which could result in bias of the risk estimates. The potential for confounding depends directly on the extent to which the variation in exposure among individuals is not random but instead has a relationship with health outcomes. Higher rates of adverse reproductive outcomes have been found in groups of lower socioeconomic status (Starfield et al., 1991), which could be related in part to less healthy behavior during pregnancy. If healthier behavior is protective against adverse pregnancy outcomes, the patterns found in our study could help identify potential confounders to consider for DBP or other drinking water exposures. This is, however, complicated by the different pathways of DBP exposure (ingestion, inhalation, and dermal absorption), and the impact would therefore be expected to differ depending on which specific DBP class or species might be important. Adjusting for individual characteristics as confounders in epidemiologic studies is likely to be important, but it might also be informative to consider them as effect modifiers in order to fully explore the impact of exposure on pregnancy health in different subgroups. The results of our study should help to guide future epidemiologic studies and risk assessments of the effect of DBPs on pregnancy outcomes.

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