Drinking water consumption patterns of residents in a Canadian community

A. Q. Jones, C. E. Dewey, K. Doré, S. E. Majowicz, S. A. McEwen and D. Waltner-Toews

ABSTRACT

A cross-sectional survey using computer-assisted telephone interviewing was performed to assess the drinking water consumption patterns in a Canadian community, and to examine the associations between these patterns and various demographic characteristics. The median amount of water consumed daily was four 250 ml servings (1.0 l), although responses were highly variable (0 to 8.0 l). Bottled water consumption was common, and represented the primary source of drinking water for approximately 27% of respondents. Approximately 49% of households used water treatment devices to treat their tap water. The observed associations between some demographic characteristics and drinking water consumption patterns indicated potential differences in risk of exposure to waterborne hazards in the population. Our results lend support to the federal review of the bottled water regulations currently in progress in Canada. Additionally, they may lend support to a provincial/territorial government review of bottled water regulations, and both federal and provincial/territorial level reviews of the water treatment device industry. Further investigation of the use of alternative water sources and the perceptions of drinking water in Canada is also needed to better understand, and subsequently address, concerns among Canadians.

Key words | bottled water, consumption patterns, drinking water, public perceptions, water treatment devices

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INTRODUCTION

Water is a crucial component for proper functioning of the body, and its importance is further reflected in the disease and deleterious health effects it can cause when contaminated. Contaminated water remains an important cause of both endemic and epidemic gastrointestinal disease throughout the world (Daschner *et al.* 1996; WHO 2004). In Canada, numerous epidemics of waterborne gastrointestinal illness have been reported (Alary & Nadeau 1990; Moorehead *et al.* 1990; Millson *et al.* 1991; Isaac-Renton *et al.* 1994; Beller *et al.* 1997; Bruce-Grey-Owen Sound Health Unit 2000; Stirling *et al.* 2001). While attempts to determine the water consumption patterns of residents are often made during investigations of such epidemics, this information is usually restricted to specific populations and limited periods of time. Estimates of drinking water consumption characteristics are useful for studies of waterborne illness, and are also required for waterborne risk assessments and the formation of water quality guidelines (Health and Welfare Canada 1981; Ershow & Cantor 1989; US Environmental Protection Agency 1997, 2000; Levallois *et al.* 1998; Lee *et al.* 2002).

Several extensive, national-based studies have examined the drinking water consumption patterns of Canadians (Health and Welfare Canada 1981) and Americans (Ershow & Cantor 1989; Roseberry & Burmaster 1992; Lee *et al.* 2002). The Canadian study however, used data collected

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during 1977–1978; hence, the results, while important, may not reflect the current consumption patterns of Canadians. Other researchers have collected data on water consumption patterns for descriptive purposes (Auslander & Langlois 1993; Levallois *et al.* 1998) and to explore the relationship between drinking water and endemic gastrointestinal disease in specific Canadian communities (Payment *et al.* 1991, 1997, 2000; Aramini *et al.* 2000). To obtain representative estimates of the water consumption patterns of the overall Canadian population, however, a population-based survey is required. As a preliminary step to any nation-wide studies, a pilot study was performed in the City of Hamilton, Ontario, Canada, between September 2001 and March 2002. This study was a subsection of a larger investigation of endemic gastrointestinal illness in the community (Majowicz *et al.* 2004). The purpose of this paper was: (a) to describe the drinking water consumption patterns of residents of the City of Hamilton, including the amount of water consumed daily and the use of alternative drinking water sources (which included commercially bottled water and water treated with in-home water treatment devices), and (b) to examine the association between water consumption patterns and various demographic characteristics of the residents.

METHODS

Study design and sampling

A telephone questionnaire was administered, in English, to a random sample of residents of the City of Hamilton, between September 2001 and March 2002. The sampling frame was a commercial database of residential telephone numbers of households in Hamilton (SelectPhone, InfoUSA, Inc., Nebraska). One individual within each household was randomly chosen to participate in the survey by selecting the individual whose birthday fell next in time. Proxy respondents were used for all individuals less than 12 years of age, and for individuals 12 to 18 years of age at the discretion of the parent or guardian. Respondents were informed that the survey was voluntary and confidential, and that they had the opportunity to skip questions at any time. The Human Subjects Committee at the University of Guelph and the Research Ethics Board of St Joseph's Hospital and McMaster University approved the study.

Questionnaire

The telephone survey investigating endemic gastrointestinal disease began in February 2001 (Majowicz *et al.* 2004), and questions pertaining to drinking water consumption were added approximately six months later. As such, the sample size for the current study was not predetermined. Of the 4,703 eligible subjects contacted over the 6-month period, 1,757 resulted in complete interviews, yielding a response rate of 37.4% (1,757/4,703). Development and pre-testing of the telephone questionnaire is described elsewhere (Majowicz *et al.* 2004). Trained interviewers at the Center for Evaluation of Medicines (St Joseph's Hospital, Hamilton/McMaster University) administered the questionnaire to participants using computer-assisted telephone interviewing.

Data collected

Amount of water consumed

Interviewers asked participants how many 250 ml servings of water they consumed during the previous 24-hour period, and this volume was defined as the total daily water intake for the respondent. Participants were informed that this could include water consumed plain as well as that used in the preparation of cold beverages, including frozen juices and juice powders. The volume of 250 ml was also presented to respondents as an 8-oz serving, one cup, and other recognized measurements, including a standard small carton of milk, and half of a regular sized bottled of water, in order to help minimize misclassification in the amount of water consumed.

Bottled water consumption

The quantity of commercially bottled water consumed was obtained from all respondents who reported drinking any water in the day prior to the interview. For summary purposes, the terms 'bottled water use' and 'bottled water user' were applied to a respondent if 75% or more of their total daily water intake consisted of bottled water. Other-

wise, respondents were classified as 'non-bottled water users'.

In-home water treatment devices

Respondents were asked about their household's use of in-home water treatment devices, including the specific device utilized. Specific types of device were grouped into categories based on function. Stove-top boiling was included and considered a 'device'. Water distillers and ultra-violet (UV) light treatment devices were classified as 'heat and light' devices. Water softeners and ozone disinfection units were classified as 'ion-based' devices, and water main filters, well filters, cistern filters, iron removal devices and refrigerators with water-dispensing filters were classified as 'other' devices.

Demographic variables

Survey respondents reported their age, sex, education level (for respondents older than 18 years), and the cultural group with which they most identified. Individuals were also asked for the total income and urban/rural status of the household.

Day of week

The effect of day of week on water consumption patterns was investigated. It was hypothesized that this effect would be limited to differences between weekday and weekend consumption. Therefore, a dichotomous variable was created to code Monday through Friday as a weekday, and Saturday and Sunday as a non-weekday. Because no initial interviews were conducted on Sundays, and the questionnaire pertained to the day prior to the interview, very few data pertaining to Saturday consumption were collected.

Data management

Fifty-six people (3.2% of respondents) reported their age as a range rather than a number. There was no difference between using the lower age limit compared with the upper age limit in univariate analyses, hence where ranges were given, the lower age limits were used in the analyses. For 51 individuals not providing their age, the mean value of the age variable was substituted for missing values in this category. Age was recorded as the number of years, except where the individual's age was less than 2 years. In these cases, children less than 12 months old were coded as zero, while children aged 12 to 18 months were coded as 1 year, and children aged 18 to 24 months were coded as 2 years.

Five per cent (89/1,730) and 0.2% (4/1,630) of responses for the total amount of water consumed and the amount of bottled water consumed, respectively, were given as ranges. In these instances, the mean values of the ranges were used. All data screening and entry was performed in Microsoft® Excel 2000. Data coding was performed in Microsoft® Excel 2000 and STATA for Windows version 7.0 (STATA Corporation, College Station, Texas).

Statistical methods

Univariate analyses

Continuous variables were tested for normality using normal-quantile plots and the Shapiro-Wilk and Anderson-Darling tests of normality. The Mann-Whitney/Wilcoxon Rank Sum test was used to test the univariate associations between the amount of water consumed and sex, day of week of water consumption, urban/rural status, in-home treatment of water and bottled water use. The Kruskal-Wallis test was used to explore the univariate associations between the amount of water consumed and education level, cultural group and income level.

Standard R × C contingency table chi-square analyses and odds ratios were employed to separately examine the association between bottled water use and all of the demographic variables, in-home treatment of water, and day of week of consumption. Chi-square analyses were also performed to assess the association of household income level and urban/rural status with water treatment device use in general, as well as with the specific type of treatment device used. As the data pertaining to treatment devices were measured as household level factors, associations were examined only with those factors that were also measured at the household level. When expected values were less than 10 in any cell of an R × C table, Monte-Carlo simulations with 100,000 repetitions were employed to account for sparse data and to obtain more accurate estimations of the

chi-square p-value (Sears 2001). The Cochran-Armitage trend test was used to test the *a priori* hypothesis that the probability of using a specific treatment device changed with increasing income categories. Finally, a chi-square contrast was used to test hypotheses of associations between urban/rural status and specific treatment device types.

Multivariable analyses

For all putative associative variables, causal diagrams were constructed to identify potential paths of associations between the predictor variables and the outcomes, and potential confounding and intervening variables. Due to problems with the cultural group data including very small sample sizes in some of the groups, the utility of cultural group as a variable was questioned, and it was therefore excluded from statistical analyses. For all regressions, a manual stepwise backward elimination procedure was employed, and all variables unconditionally associated with the outcome at $p < 0.3$ were initially included in the model. The significance level was set at 5% ($p < 0.05$) for all final analyses.

Least squares regression was used for the multivariable analysis of the amount of water consumed. Due to the non-normal nature of the data, a value of one was added to all responses of the outcome variable (the amount of water consumed), followed by a quarter-root transformation. The presence of confounding and interaction among the remaining variables in the model was then investigated, and standard residual analysis performed. As a normality transformation was used, the interpretation of the coefficients of the model required special consideration. Outcomes were calculated for a wide range of continuous variable values at each level of all categorical variables in the model. The outcomes were then back-transformed and displayed graphically.

Logistic regression modelling was used for the multivariable analysis of bottled water use. The assumption of linearity was tested and, where required, polynomial terms of the continuous predictors were created and tested in the logistic model. Where there was evidence of collinearity (intra-class correlation coefficient: $|\rho| > 0.8$) centering of the highly correlated variables was performed. The presence of confounding and interaction among the remaining variables in the model was investigated. The goodness-of-fit and the predictive ability of the model were assessed, and standard residual analyses were performed. Graphical techniques were employed to assess the association of bottled water use with the predictor variables in the model. All statistical analyses were performed in STATA for Windows version 7.0, with the exception of the performance of the Monte-Carlo simulations and trend tests, for which an in-house Fortran program was used (Sears 2001).

RESULTS

Amount of water consumed

Responses for the amount of water consumed per day were received from 1,730 respondents. Total daily water intake ranged from zero to thirty-two 250 ml servings per day, with a median value of four 250 ml servings (1.0 l) (Table 1). Overall, 6.7% (116/1,730) of respondents consumed no water, 35.7% (617/1,730) consumed a 'small' amount of water (less than four servings), 50.2% (868/1,730) consumed a 'moderate' amount of water (between four and

Table 1 | Number of 250 ml servings of water consumed per person per day, reported by residents in the City of Hamilton, Ontario (Canada), between September 2001 and March 2002

Percentile	Total amount of water* consumed (n = 1,730)	Amount of bottled water consumed (n = 1,630)	Amount of bottled water consumed among consumers of bottled water (n = 652)
1%	0	0	1
5%	0	0	1
10%	1	0	1
25%	2	0	2
50%	4	0	3
75%	6	3	5
90%	8	5	8
95%	10	7	8
99%	15	10	16

*Regardless of type of water (tap, bottled, treated)

eight servings), and 7.5% (129/1,730) consumed a 'large' amount of water (more than eight servings) in the previous day. Unconditional analyses of the associations of various demographic variables and alternative water types with the amount of water consumed are shown in Table 2.

In the multivariable analyses, the amount of water consumed was associated with age, in-home treatment of water and education level (Figure 1a and b). Overall, consumption decreased with increasing age, and was higher in respondents with education levels above the referent group, defined as 'less-than high-school'. Residents using in-home water treatment devices also consumed more water daily (Figure 1a versus Figure 1b). The overall model was significant ($p = 0.001$), with an adjusted-R^2 of 1.39%.

Bottled water consumption

Responses for the amount of bottled water consumed per day were received from 1,630 respondents (Table 1). Data regarding the percentage of the total daily water intake that was bottled water were available for 1,610 respondents. Bottled water was not consumed by 59.7% (961/1,610) of respondents. Bottled water represented a 'small' (<25%), 'moderate' (between 25 and 74%) and 'large' (>75%) proportion of total daily water intake for 1.9% (30/1,610), 11.1% (179/1,610) and 27.3% (440/1,610) of respondents, respectively. Therefore, approximately 27% of respondents were classified as 'bottled water users'. The chi-square analyses of bottled water use with the putative associative factors, and the proportion of residents classified as bottled water users when categorized by these factors, are shown in Table 3.

Based on the initial causal diagram of bottled water use (Figure 2), it was hypothesized that education, income and treatment of water would be intervening variables for cultural group and age in their association with bottled water use. The data did not, however, support this hypothesis, as inclusion of the potential intervening variables did not change the significance or the coefficients for cultural group and age. The final multivariable model of bottled water use included the centred linear and quadratic age terms, and the variables representing the in-home treatment of water and day of week of consumption. The model fit the data well (Pearson $\chi^2 = 322.4$, $p = 0.4$; Deviance $\chi^2 = 350.2$, $p = 0.1$); however its predictive ability was only fair, as assessed by a receiver operating characteristic curve (area under curve = 0.64). Owing to the use of a polynomial age term, the association of age with bottled water use was interpreted graphically (Figure 3). The general trend, regardless of in-home water treatment status and day of week, was a steady increase in the probability of bottled water use with increasing age to a peak at approximately 31 years of age, and then a steady decline with increasing age. Further, controlling for age and day of week, the odds of being a bottled water user for an individual that used in-home water treatment devices was 0.5 times that of an individual that did not use such devices (95% confidence interval: 0.40 to 0.63, $p < 0.0001$). Controlling for age and use of treatment devices, the odds of bottled water use for weekdays were 0.73 times that for weekends (95% confidence interval: 0.55 to 0.98, $p = 0.03$).

In-home water treatment devices

Responses regarding the use of in-home water treatment devices were received from 1,752 respondents, and approximately 49% of respondents (860/1,752) reported using such devices to treat their tap water. The specific types of treatment device used are summarized in Table 4. The most common were jug filters (66.2%), followed by tap filters (16.3%) and boiling (6.8%). Approximately 2.5% of households (44/1,752) used two water treatment devices. Of respondents for whom the status of both bottled water and treatment device use was known, approximately 10% (160/1,609) were classified as bottled water users and used water treatment devices.

Household income level was not significantly associated with the use of in-home water treatment devices ($\chi^2 = 4.5$, $p = 0.34$). Further, there was no overall association of household income with specific treatment device types ($\chi^2 = 28.53$, $p = 0.24$); however, more households in the lowest income level (< US$20,000) used boiling as a water treatment than was expected under the null hypothesis (13 observed versus 5.9 expected). In a linear contrast of income, the probability of the use of boiling or jug-filters in households in the lower income levels was higher than that of households in the higher income levels. Conversely, households with higher incomes had a higher probability of

Table 2 | Summary statistics and univariate associations between the amount of water consumed and putative associative factors, for 1,730 residents of Hamilton, Ontario (Canada), from September 2001 to March 2002

	Number of residents	Mean consumption of water (250 ml servings)	Standard deviation (250 ml servings)	25th percentile (250 ml servings)	50th percentile (250 ml servings)	75th percentile (250 ml servings)
Age (years); ($p = 0.0001$)						
<5	70	3.1	1.9	2	3	4
5 to 9	69	3.8	1.8	3	4	5
10 to 14	73	3.7	2.0	2	3.5	5
15 to 19	70	4.7	3.0	3	4	6
20 to 29	187	4.9	3.1	3	4	7
30 to 39	252	4.7	2.9	3	4	6
40 to 64	671	4.7	3.5	2	4	6
>65	290	4.0	2.6	2	4	5.5
Unknown	48	4.5	3.4	3	4	6
Education level ($p = 0.0001$)						
Less than high school	286	4.1	3.0	2	4	6
High school	573	4.7	3.6	2	4	6
College/trade school	232	4.5	3.0	2	4	6
University/graduate/medical school	322	4.8	2.8	3	4	6.5
Not asked (<18 years old)	245	3.7	2.0	2	3	5
Unknown	72	4.3	2.5	3	4	5.8
In-home water treatment status ($p = 0.02$)						
Yes	847	4.6	2.9	3	4	6
No	879	4.3	3.2	2	4	6
Unknown	4	2.3	2.1	0.5	2.5	4
Sex ($p = 0.15$)						
Male	704	4.4	3.1	2	4	6
Female	1,019	4.5	3.0	3	4	6
Unknown	7	4.6	2.9	2	6	7

Table 2 | (*Continued*)

	Number of residents	Mean consumption of water (250 ml servings)	Standard deviation (250 ml servings)	25th percentile (250 ml servings)	50th percentile (250 ml servings)	75th percentile (250 ml servings)
Cultural group ($p = 0.29$)						
North American	1,407	4.5	3.1	2	4	6
South American	12	4.3	2.3	3	4.5	6
European	224	4.0	2.8	2	4	6
African	13	6.4	4.3	3	5	8
Asian	44	4.5	2.5	3	4	6
Aboriginal	9	5.7	3.9	2	6	8
Other	11	4.0	2.4	2	4	6
Unknown	10	4.7	2.1	4	4	6
Household income (US$1,000 s) ($p = 0.80$)						
<20	151	4.5	3.5	2	4	6
20 to 39	227	4.5	3.0	2	4	6
40 to 59	290	4.6	3.4	2	4	6
60 to 79	213	4.4	2.6	3	4	6
>80	254	4.6	2.7	3	4	6
Unknown	595	4.3	3.1	2	4	6
Urban/rural status ($p = 0.91$)						
Urban	1,474	4.5	3.1	2	4	6
Rural	253	4.3	2.6	3	4	6
Unknown	3	4.0	0	4	4	4
Bottled water use ($p = 0.69$)						
Yes	427	4.9	3.3	3	4	6
No	1,183	4.7	2.8	3	4	6
Unknown	120	0.13	0.86	0	0	0
Day of week; ($p = 0.47$)						
Weekend	302	4.6	3.3	3	4	6
Weekday	1,428	4.4	3.0	2	4	6

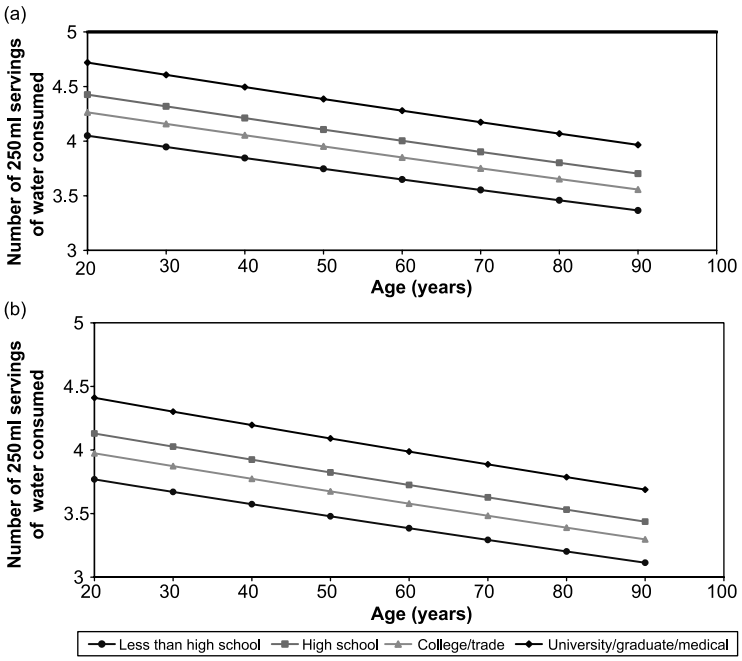

Figure 1 | Effect of age and education level on the amount of water consumed by adult individuals (a) using water treatment devices, and (b) not using water treatment devices, as derived from a least squares regression model using data collected from 1,726 residents of Hamilton, Ontario (Canada), between September 2001 and March 2002.

using heat and light based, ion-based and reverse osmosis devices than households in the lower income levels (contrast $\chi^2 = 14.2$, $p = 0.0002$). The observed relationships were linear (contrast χ^2 for curvature $= 0.07$, $p = 0.79$).

Although not significant at the level of 5%, the odds of using in-home treatment devices for rural residents was 1.3 times that for urban residents ($p = 0.10$). There was an association between water treatment device type and urban/rural status ($\chi^2 = 57.8$, $p < 0.00001$). Specifically, compared with urban residents, rural residents used jug-filters and boiling less than expected under the null hypothesis, but used heat and light based, ion-based and 'other' devices more than expected under the null hypothesis.

DISCUSSION

This study investigated the drinking water consumption patterns in a Canadian community, including regular tap water (municipal and that from private water sources) and water from alternative sources. This information could potentially be used in waterborne risk assessments and in the formation of water quality guidelines. A particular advantage of this study was the availability of data pertaining to the drinking water consumption patterns of Canadian children.

Amount of water consumption

The amount of water consumed in this population was highly variable, which could reflect true differences in water consumption among residents. Reasons for variation in the amount of water consumed among residents were not investigated here, but can include personal preferences, physical activity, medications and pregnancy (Ershow & Cantor 1989). Further, the main focus of this paper was to describe general water consumption patterns and to determine factors that may be associated with those patterns, not to specifically predict the amount of water consumed daily. Therefore, data on important variables affecting water consumption, including body weight and activity level were not collected. As such, while the overall model was significant, it explained little variance in the outcome as evidenced by the poor adjusted-R^2 value. The model, in its current form, should not be used to predict

Table 3 | Bottled water use by putative associative factors for residents of Hamilton, Ontario (Canada), from September 2001 to March 2002

Putative associative factors		Total number of respondents	Bottled water users* (proportion)
Age (years) ($p < 0.0001$)	Less than 5	64	0.30
	5 to 9	67	0.24
	10 to 14	69	0.26
	15 to 19	68	0.31
	20 to 29	174	0.32
	30 to 39	242	0.32
	40 to 64	616	0.30
	65 and above	269	0.12
	Total	1,569	
Education level ($p = 0.29$)	Less than high school	260	0.22
	High school	532	0.30
	College/trade school	214	0.30
	University/graduate/medical school	307	0.25
	Under age	231	0.28
	Unknown	66	0.27
	Total	1,610	
In-home water treatment status ($p < 0.0001$)	Yes	791	0.20
	No	818	0.34
	Total	1,609	
Sex ($p = 0.99$)	Male	654	0.27
	Female	950	0.27
	Total	1,604	
Cultural group ($p = 0.09$)	North American	1,320	0.26
	South American	11	0.36
	European	198	0.35
	African	13	0.15
	Asian	41	0.29
	Aboriginal	8	0
	Other	10	0.30
	Total	1,601	
Household income (US$1,000 s) ($p = 0.19$)	<20	135	0.19
	20 to 39	211	0.27
	40 to 59	271	0.28
	60 to 79	203	0.31
	>80	240	0.25
	Total	1,060	
Urban/rural status ($p = 0.34$)	Rural	235	0.30
	Urban	1,373	0.27
	Total	1,608	
Day of week of water consumption ($p = 0.14$)	Sunday	278	0.31
	Weekday	1,332	0.27
	Total	1,610	

*A resident for whom bottled water represented 75% or more of their total daily water intake

water consumption, and was instead used only to examine the association of variables with the amount of water consumed.

This study measured only plain water and water used to prepare cold beverages, while others have also included water used to prepare hot beverages and/or food (Health and Welfare Canada 1981; Ershow & Cantor 1989; Payment 1991, 1997, 2000; Levallois *et al.* 1998; US Environmental Protection Agency 2000). Levallois and colleagues (1998) found that approximately 46% of respondents' total daily water intake was consumed in the latter regard, although with the exception of soup and cereal, water intake via food was limited to an average of 0.016 l day^{-1}. We initially assumed that cooking/boiling would eliminate most waterborne pathogens; however, this may not be correct in that the boiling point may not be reached for long enough periods during these processes. For this reason, and to evaluate the total water consumption of residents, it may be ideal in future studies to assess water consumed as plain water, as well as that used to prepare cold and hot beverages, soups and cereals.

Consumption in the present study reflects that in the previous 24-hour period. While this may be beneficial in terms of accuracy of respondent recall, it will not capture day-to-day variations in consumption, and measurements may not be reflective of the usual water consumption for the individual. The study design used by Levallois *et al.* (1998), for example, which was both prospective and retrospective in nature and used daily water consumption diaries, is likely to be the ideal for reducing recall bias and obtaining representative measurements of water consumption. It is also, however, significantly more demanding of the investigators and respondents (Levallois *et al.* 1998), which could contribute to low response rates, as in Levallois' study.

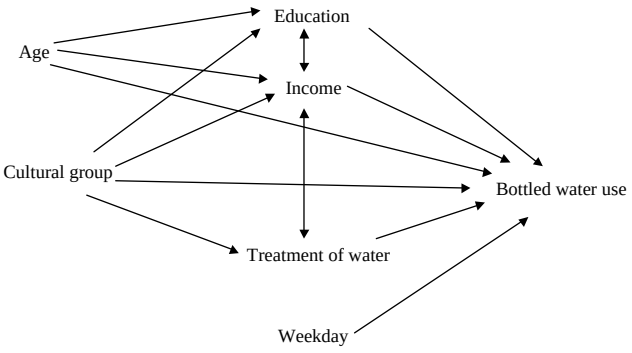

Figure 2 | Proposed causal diagram of the associations of explanatory variables with the outcome, bottled water use.

When study design differences are considered, the estimated amount of water consumed per day in this study was not substantially different from previous Canadian estimates; however, there were important differences observed in the type of water consumed. Specifically, the use of alternative drinking water, including bottled water and tap water treated by in-home water treatment devices, was higher in this study compared with others.

Bottled water consumption

Bottled water often represented 75% or more of the total daily water intake, and was used more frequently than was observed in other studies. Lee and colleagues (2002) reported that 17.8% of 12,755 respondents in the US identified bottled water as their primary source of drinking water. Unfortunately, the term 'primary' was not explicitly defined. Auslander and Langlois (1993) found that 19.5% of surveyed households in Toronto, Ontario, were 'regular bottled water users', where regular bottled water use was defined as greater than 50% of total water consumption consisting of bottled water. Had we used the cut-point of 50%, then 33% of respondents in our study would have been classified as bottled water users. Temporal differences in the study periods could account for the observed difference in bottled water use among our respondents and those of the other studies. Since 1997, bottled water has grown from 25% to 40% of total annual beverage sales in Canada (Kohane 2002). Since the present study's time frame was 2001–2002, while those of Auslander and Langlois, and Lee and colleagues were 1988 and 1998–1999, respectively, the increased use of bottled water observed in this study might reflect higher bottled water availability. Presumably, it might also relate to changes in the perception of tap water after a large and highly publicized waterborne outbreak of *Escherichia coli* 0157:H7 in Walkerton, Ontario, in 2000, or to differences in the public perception of drinking water in Hamilton, compared with the other study sites.

The association of bottled water use with age probably represents a cohort or generational effect, rather than a period effect. The current use of bottled water among

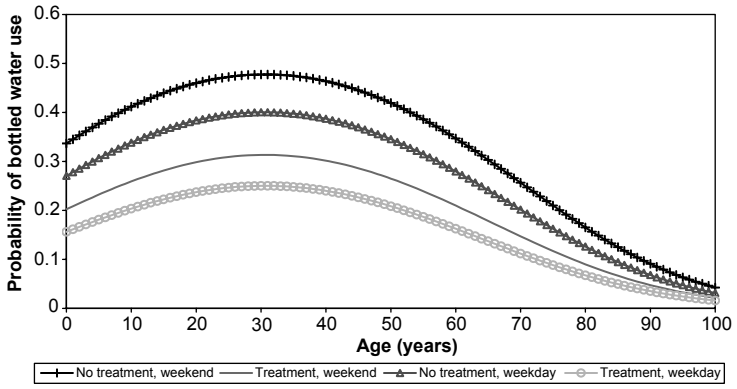

Figure 3 | The probability of bottled water use by age, in-home water treatment status and day of week, as derived from a logistic regression model using data collected from 1,609 residents of Hamilton, Ontario (Canada), between September 2001 and March 2002.

members of the 30–40-year-old age cohort is likely to influence their use of bottled water in the future. Hence, where members of the 60–70 year age cohort were not observed to have a high probability of bottled water use in this study, it can be expected that, in 30 years, bottled water use in this age group will be more common. Similarly, the current use of bottled water in respondents less than 20 years of age probably reflects the attitudes and preferences of their parents/legal guardians. In 20 years, it might be expected that the probability of bottled water use among the 20–40-year-old group will be higher than observed here.

Table 4 | The types of in-home water treatment device used to treat tap water in Hamilton, Ontario (Canada), as reported by 860 households between September 2001 and March 2002

Water treatment device	Frequency	Percentage
Jug filter	589	66.2
Tap filter	145	16.3
Boiling	61	6.8
Heat/light treatment	24	2.7
Reverse osmosis	24	2.7
Ion-based treatment	21	2.4
Other	26	2.9
Total	890*	100

*Exceeds number of respondents as some respondents used two treatment devices

With the exception of minor amendments in the 1980s, current bottled water regulations have not changed significantly since their establishment in 1973. With many more people now being exposed to bottled water, increased attention to this commodity is warranted. A review of bottled water regulations by the Canadian federal government is currently under way for a number of reasons, including the incorporation of new scientific knowledge, the accommodation of new products, and to bring the regulations in line with the Guidelines for Canadian Drinking Water Quality (Canadian Food Inspection Agency & Health Canada 2002). These results may also remind drinking water researchers, and others with public health mandates, of the common use of bottled water and the importance of considering bottled water in their drinking water studies and programmes. Provincial/territorial authorities, for example, may want to consider establishing their own bottled water standards, perhaps similar to those used by the Canadian Bottled Water Association, which are stricter than the federal regulations currently in place.

In-home water treatment devices

Nearly half of the respondents reported that their households used an in-home water treatment device to treat their tap water. This estimate is higher than those of other studies. Auslander and Langlois found that only 11% of 200 households in Toronto, Ontario, used treatment devices (Auslander & Langlois 1993). In the study by Lee and colleagues (2002), 30% of 12,755 households surveyed in

the US used water treatment devices. Again, temporal differences in study periods might account for this difference, as it is estimated that as many as 100,000 water treatment devices are sold annually in Canada (Health Canada 2003). Approximately 82% of devices used in the present study were jug and tap filters, which typically employ activated carbon filtration. The common use of these treatment methods could possibly relate to the relative low-cost and/or ease of use of these devices compared with the other methods observed.

The large proportion of households using treatment devices could indicate the need for several actions. In general, consumers expect these devices to be efficacious in improving the safety and aesthetic qualities of their tap water (Auslander & Langlois 1993; Lee *et al.* 2002). Although we did not measure the effectiveness of water treatment devices, nor examine their association with health outcomes, other studies have demonstrated the potential for post-treatment water to be of poorer chemical and/or microbiological quality than municipal tap water entering the device (Daschner *et al.* 1996; Health Canada 2003). Paradoxically, there is therefore potential for individuals using in-home water treatment devices to be at greater risk for waterborne illness as a result of misuse of the device. As such, expansion of public education with respect to the proper use of common water treatment devices, and the potential risks of misuse, may be warranted. Consumers should also be informed of Health Canada's recommendation to purchase only those devices certified with the National Sanitation Foundation, a not-for-profit organization that tests water treatment systems to verify manufacturer claims. This information is currently available on government websites (Health Canada 2003), and further dissemination may prove beneficial. The current lack of specific legislation pertaining to the regulation of water treatment device manufacturing in Canada (Health Canada 2003) should also be reviewed in the light of the public's common use of these devices.

Factors associated with water consumption patterns

Associations between demographic characteristics and water consumption patterns were investigated to identify the types of individual that may be at greater or lesser risk for waterborne illness, either through differences in the volume or the type of water consumed. In terms of acute exposures/illnesses, the differences in the amount of water consumed by different demographic groups were not likely to be large enough to be of practical significance. The differences may be significant, however, in terms of risks from chronic exposures, such as from waterborne chemicals or microbes. Further investigation of the relationships of water consumption patterns with demographic variables, on a larger Canadian scale, would be useful in this regard.

There were observed differences in the probability of bottled water use among different ages, particularly when the elderly were compared with 20- to 40-year-olds. If bottled water was sufficiently different from tap water in terms of microbiological and chemical safety, this difference could potentially lead to differences in exposure to waterborne hazards among different age groups. Similarly, the differential use of the more sophisticated treatment devices among the income categories could also potentially result in differences in risk between these groups.

Determining motives for alternative water use

A large proportion of respondents in this study consumed alternative drinking water, including commercially bottled water or tap water treated with a treatment device. A previous Canadian study found reasons for such alternative water use to include improved safety and aesthetics compared with regular tap water (Auslander & Langlois 1993). These results may not be representative of the general population, however, given the small sample size. The reasons behind alternative water use in Canada should be further investigated. The authors are currently conducting follow-up studies using a series of in-depth focus groups and a larger-scale mail survey in this study population. It is important to know whether alternative water use is frequent and based on concerns over the quality and safety of regular municipal water. If this were the case, it could indicate a need for increased sharing of water quality guidelines and safeguards with the public, and/or a review and modification of current water regulation and treatment protocol. If such measures were taken, and openly shared with the public, it could lead to improved public perception of

municipal water and, hence, better use of this essential resource to which significant time and expense are already dedicated.

Limitations

Although the sample size was not determined *a priori*, this is unlikely to have had a significant effect on the precision of the estimates given the large number of respondents. However, selection bias is possible due to the overall response rate of 37.4%. The low response is probably related to the nature of the questionnaire and the high frequency with which telephone health surveys are administered in the study area (Majowicz *et al.* 2004). A potentially important source of bias in the estimates presented here was the administration of the survey in English only. However, according to Statistics Canada 2001 census data of the City of Hamilton, approximately 97% of the population is able to converse in English so any selection bias due to language barriers is likely to have been minimal. Further, despite having the importance of income data explained as well as having the confidentiality of the survey re-stated, a large proportion (611/1,757 or 35%) of respondents declined to answer the question regarding household income. Therefore, in addition to the possibility of insufficient power to detect differences between income levels, the income data may be biased. There was also insufficient power to detect differences in the amount of water consumed between cultural groups because of the small number of observations in some of the cultural groupings. Lastly, this was a pilot study; hence, the study population is limited to one municipality, and water consumption was investigated only over a 6-month period; hence seasonal patterns in consumption may have been missed.

CONCLUSIONS

The median water consumption in this population was 1.0 l per day, although responses were highly variable. Consumption patterns were associated with day of week of consumption and with some respondent characteristics, including age, education level and use of water treatment devices. These associations could potentially help to identify those types of individual who may be at greater risk of waterborne hazards. A high proportion of respondents used alternative water sources such as bottled water and tap water treated with in-home treatment devices. In addition to drawing attention to the common use of bottled water, these results may prompt provincial/territorial governments to review current bottled water regulations and consider establishing stricter standards, perhaps similar to those of the Canadian Bottled Water Association. Additionally, they lend support to the current federal review of bottled water regulations in Canada. Given the common use of water treatment devices, studies assessing the association between these devices, water quality and health outcomes are needed. Similarly, in order to take proactive measures for public health, it may be important to review the need for regulation of water treatment devices, as well as expand public education with respect to their use.

The results of the present study are limited to a specific population; hence, it seems prudent to further investigate the general water consumption patterns and the use of alternative drinking water sources in Canada. Further investigation of the public perceptions of drinking water also appears warranted. The results of this pilot study thus indicate the need for a full-scale national study, and suggest some important lines of enquiry.

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