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A survey of risk factors for cryptosporidiosis in New York City: drinking water and other exposures

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SUMMARY

We conducted a survey to determine the prevalence of known and theoretical exposure risks for cryptosporidiosis among selected New York City residents. Subjects were recruited from outpatients attending either a practice for persons with HIV infection ($n = 160$), or other medical practices ($n = 153$), at The New York Hospital–Cornell Medical Center. Despite a greater concern for waterborne infection, 82% of HIV-infected subjects reported consuming municipal tap water compared to 69% of subjects from other medical clinics (OR 2·1, 95% CI 1·2–3·6, $P = 0·006$). Although 18% and 31% of subjects, respectively, denied any tap water consumption at home or work, all but one from each cohort responded positively to having at least one possible alternate source of tap water ingestion such as using tap water to brush teeth or drinking tap water offered in a restaurant. 78% and 76% of subjects, respectively, had at least one potential risk for exposure other than municipal water consumption, such as swimming in pools or contact with animals. Our findings indicate that it is possible to stratify the population into subsets by the amount of tap water consumed. This suggests that an observational epidemiologic study of the risk of contracting cryptosporidiosis from everyday tap water consumption is feasible.

INTRODUCTION

The protozoan *Cryptosporidium parvum* can be transmitted to humans from several different sources, including drinking water, contact with infected humans and animals, consumption of contaminated food, and swimming in pools and fresh water [1–16]. Any activity where there is the potential for ingestion of material contaminated by even a small amount of faeces from infected humans or animals [1–5, 16–18] could pose a risk. However, the relative importance of these routes of transmission in causing sporadic cryptosporidiosis remains unknown. The largest cryptosporidiosis outbreaks [19–23], the best known of which resulted in 403000 cases in Milwaukee, Wisconsin in 1993 [21], have been attributed to contaminated municipal drinking water, prompting concern over the safety of day-to-day water consumption.

However, apart from such outbreaks, transmission of *Cryptosporidium* from public water supplies has yet to be demonstrated, either because the risk is small and not investigated or because the association between sporadic human cryptosporidiosis and water consumption has simply escaped detection. Recognition of sources of exposure is difficult since a

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relatively small inoculum may be sufficient to cause disease; DuPont and colleagues observed symptomatic infection in 3 of 8 (37·5%) healthy volunteers who ingested an intended dose of 100 *Cryptosporidium* oocysts [24]. *Cryptosporidium* oocysts are highly prevalent in surface and treated waters as documented in more than 25 published studies [3]. Oocysts (0·003–4·74/l) have been found in 5·6–87·1% of source waters sampled in the United States and Canada, and 0·002–0·015 oocysts/l have been detected in 3·8–40·1% of drinking water samples in the United States, Canada, and Scotland [3]. Pathogen monitoring of New York City source waters also revealed low-level contamination with *Cryptosporidium* oocysts in approximately 2% of samples [25, 26]. Whether oocysts detected in water are viable, infective for humans, or present in sufficient number to cause human disease is not clear [1–5, 18].

Human cryptosporidiosis is increasingly recognized as a major public health problem. Infection in healthy individuals, though self-limiting, may be protracted and result in substantial morbidity. Cryptosporidiosis is more severe in immunocompromised persons including those with congenital immunodeficiency, and those taking exogenous immunosuppression for neoplastic disease or after organ transplantation; in patients with AIDS, it is frequently chronic, debilitating, and even fatal [27]. There is as yet no known effective anticryptosporidial therapy [28]. Therefore, delineation of the risks of acquiring the infection, and development of preventive strategies, are of paramount importance.

As a step toward understanding the epidemiology of human cryptosporidiosis, we conducted a survey of 160 HIV-positive outpatients, and 153 subjects from various other medical practices with a presumed low likelihood of HIV-infection, in order to characterize drinking water consumption patterns and the prevalence of other possible sources of exposure to *Cryptosporidium*.

METHODS

The survey consisted of a comprehensive questionnaire. Subjects were drawn from among adult, English-speaking, New York City residents seen in outpatient practices affiliated with The New York Hospital–Cornell Medical Center, a large urban health care centre. All patients awaiting or having just completed scheduled appointments were approached by an interviewer who explained the study. After signing informed consent, those agreeing to participate were either surveyed then or later by telephone.

One hundred and sixty known HIV-positive subjects drawn from among patients at the Center for Special Studies, a primary care practice for HIV-infected individuals, were interviewed between August and December 1994 (Group A). A second cohort (Group B) consisted of 153 subjects recruited, without inquiry about HIV status, from ambulatory practices (general medicine, nephrology, and otorhinolaryngology) expected to have a low prevalence of HIV infection, who were surveyed between December 1994 and January 1995. Only one member per household was surveyed.

The questionnaire included items on: (1) demographic characteristics; (2) sources of drinking water; (3) exposures other than day-to-day water consumption; (4) reasons for using alternatives to municipal water; (5) and exposure to counselling or media coverage on risks for cryptosporidiosis. The range of information sought can be seen from Tables 1–4. Subjects in Group A were also asked about their HIV-related medical history.

Drinking water was defined as water consumed as a beverage or used to mix drinks or reconstitute juice; water heated for use in hot beverages was excluded because heating water above 72 °C for 1 min inactivates *Cryptosporidium* oocysts [29]. 'Tap water' was defined as water consumed directly from a tap without filtration or boiling. The proportion of a subject's home drinking water coming directly from a tap, filtered or boiled before use, or from commercially bottled water, at the time of interview, was recorded. Tap water consumption at work, and at second residences such as summer homes, was also documented. Subjects who said they drank no water directly from a tap were asked questions about other sources of tap water, such as that consumed at friends' homes, restaurants, or in ice cubes since *Cryptosporidium* oocysts can withstand some degree of freezing [29].

Exposure to risks other than municipal water consumption were scored as present or absent during the 6 months prior to interview. These risks are defined as 'recognized' and 'potential'. 'Recognized risks' are activities that have been implicated in cryptosporidiosis outbreaks, e.g. swimming in pools or attending day-care centres, and activities acknowledged to be high risk, e.g. sexual activity involving oral–anal contact. 'Potential risks' include

Table 1. *Demographic characteristics, by study cohort*

Characteristic	Cohort Group A $n = 160$ (%)	Group B $n = 153$ (%)
Sex		
Female	44 (28)	100 (65)*
Male	116 (72)	53 (35)
Age		
$\leqslant$ 30 years	20 (12)	52 (34)†
31–50 years	126 (79)	55 (36)
> 50 years	14 (9)	46 (30)
Mean ± S.D.	39 ± 8 years	41 ± 16 years
Ethnicity		
Black	46 (29)	48 (31)
Hispanic	31 (19)	9 (6)‡
White	77 (48)	82 (54)
Other	6 (4)	14 (9)
Education		
No high school degree	25 (16)	14 (9)
High school degree	35 (22)	25 (16)
Post high school education	100 (62)	112 (73)

Significant differences between cohorts.
* Sex, $P < 0{\cdot}0001$.
† Age under 31 or over 50, $P < 0{\cdot}0001$.
‡ Hispanic ethnicity, $P = 0{\cdot}0004$.

other activities in which exposure to *Cryptosporidium*-contaminated faeces is *possible*, e.g. contact with pets [1, 30] or soil [11], but which have yet to be proven as sources of human cryptosporidiosis.

Subjects who drank water other than that taken directly from a tap were asked the duration and reasons for their use of alternatives. All subjects were asked whether they had heard of cryptosporidiosis or had ever been diagnosed as having this infection. They were also asked if they had seen or were aware of a two-part series on *Cryptosporidium* in New York City municipal water shown in September and October 1994 on the prime-time news feature programme 'Dateline NBC'. Group A subjects were asked whether they had received counselling on water or food consumption. In addition, they were asked their last CD_4 lymphocyte count and to list active and prior opportunistic infections.

Data were compiled in database format and prevalence frequencies analysed using Foxpro 2.5 (Microsoft Corp.). Correlations between exposures, demographic features, and other parameters such as motives for tap water avoidance, were evaluated by chi-squared methodology using the Mantel–Haenszel test or, when appropriate, the Fisher exact test (Epi Info 5, Centers for Disease Control and Prevention). Differences in the prevalence of exposures between cohorts were further evaluated by logistic regression analysis (SAS, SAS Institute Inc.) to control for demographic characteristics. The study was approved by the New York Hospital–Cornell Medical Center Institutional Review Board.

RESULTS

Demographics

The demographic features of Group A (HIV clinic) and Group B (other clinics) are summarized in Table 1. Group A was 72% male while Group B was only 35% male ($P < 0{\cdot}0001$). Although the mean age in each cohort was similar, there was a much narrower distribution around the mean in the HIV-infected cohort. In the latter, there were significantly fewer subjects in the $\leqslant$ 30 or > 50 year age group than in Group B (21% *vs.* 64%, $P < 0{\cdot}0001$). In addition, there were significantly more Hispanic respondents in Group A than Group B (19% *vs.* 6%; $P = 0{\cdot}0004$). These differences are addressed in the comparisons of risk factor prevalence between cohorts that follow.

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Table 2. *Tap water consumption*

Tap water exposure	Cohort Group A (%) $n = 160$	Group B (%) $n = 153$
At home		
Drink tap water	119 (74)	98 (66)
Percentage from tap		
100	28 (18)	34 (22)
76–99	44 (28)	27 (18)
51–75	12 (8)	18 (12)
26–50	10 (6)	4 (3)
1–25	25 (16)	15 (9)
Drink NO tap water	41 (26)	55 (34)*
At home, work, or second residence		
Drink NO tap water	28 (18)	47 (31)†
Drink NO tap water and NO tap water used		
As ice	17 (11)	25 (16)
At restaurants	20 (13)	29 (19)
At friends' homes	14 (9)	25 (16)
For washing/preparing foods	5 (3)	9 (6)
For brushing teeth	3 (2)	1 (< 1)
As ice, at restaurants or friends' homes	11 (7)	19 (12)
For any of the above uses	1 (< 1)	1 (< 1)

* OR 1·63 95% CI 1·004–2·6, $P = 0{\cdot}048$.
† OR 2·09, 95% CI 1·23–3·54, $P = 0{\cdot}006$.

Drinking water

Tap water consumption patterns within each cohort are presented in Table 2. Thirty-four percent of subjects in Group B, and 26% of subjects in Group A, reported drinking no tap water at home (OR 1·63, 95% CI 1·004–2·60, $P = 0{\cdot}048$). Of subjects drinking no tap water at home, Group B subjects (47/55, or 85%) were more likely to consistently avoid tap water at work or a second residence than Group A subjects (28/41, or 68%; $P = 0{\cdot}04$). Thus, when considering all drinking water consumption at home, work, and second residence, a significantly higher proportion of subjects in Group B (31%) avoided tap water than in Group A (18%, OR 2·09, 95% CI 1·23–3·54, $P = 0{\cdot}006$). This difference between cohorts remains statistically significant in a logistic regression analysis stratified by sex, age, ethnicity, and level of education (adjusted OR 2·74, 95% CI 1·51–4·97, $P = 0{\cdot}001$).

Alternative water sources for those subjects who drank no tap water at home, work, or a second residence, are shown in Figure 1. Group A subjects were more likely to drink boiled water than those in Group B (39% *vs.* 13% respectively; $P = 0{\cdot}008$). Subjects in Group B were significantly more likely to drink filtered water than those in Group A (36% *vs.* 11% respectively; $P = 0{\cdot}02$). Because many home filtration systems are ineffective in removing *Cryptosporidium* oocysts from tap water, we compared both cohorts with respect to the subset of subjects who reported drinking neither tap nor filtered water at

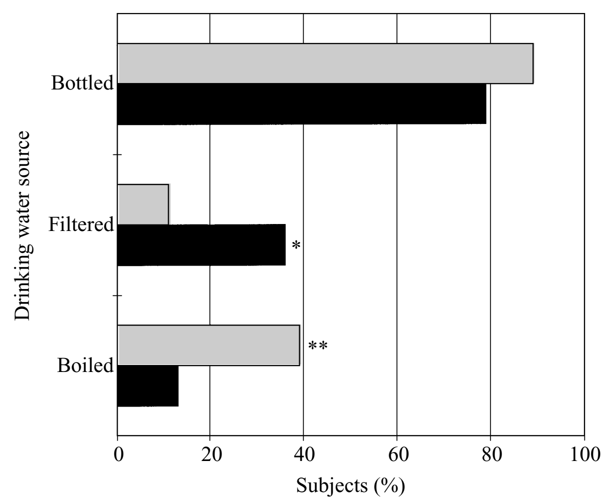

Fig. 1. Alternative drinking water sources among subjects who drank no tap water at home, work, or second residence. Some subjects: more than one source. ▨, Group A ($n = 28$); ■, Group B ($n = 47$). * $P = 0{\cdot}02$; ** $P = 0{\cdot}008$.

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Table 3. *Analysis of subjects drinking no tap water at home, work, or second residence, by demographic group*

	Cohort (%)	
Characteristic	Group A	Group B
Total*	28/160 (18)	47/153 (31)
Sex		
Female	3/44 (7)	27/100 (27)
Male	25/116 (22)§	20/53 (38)
Age		
⩽ 30 years	6/20 (30)	14/52 (26)
31–50 years	21/126 (17)	12/55 (22)
> 50 years†	1/14 (7)	21/46 (46)‖
Ethnicity		
Black‡	5/46 (11)	20/48 (42)
Hispanic	8/31 (26)	3/9 (33)
White	14/77 (18)	16/82 (20)¶
Other	1/6 (17)	8/14 (57)
Education		
No high school degree	4/25 (16)	6/14 (43)
High school degree	2/35 (6)	7/25 (28)
Post high school education	22/100 (22)	34/112 (31)

Significant difference *between* cohorts.
* Group B versus Group A, all subjects: OR 2·09, 95% CI 1·23–3·54, $P = 0·006$.
† Group B versus Group A subjects aged > 50: OR 10·9, 95% CI 1·8–66·4, $P = 0·009$.
‡ Group B versus Group A Blacks. OR 5·9, 95% CI 2·1–16·4, $P = 0·0008$.
Significant difference *between* groups *within* cohort.
§ Males versus females in Group A: OR 3·8, 95% CI 1·2–12·3, $P = 0·03$.
‖ Age > 50 years versus age ⩽ 50 in Group B: OR 2·6, 95% CI 1·3–5·4, $P = 0·009$.
¶ Whites versus all others in Group B: OR 0·31, 95% CI 0·15–0·63, $P = 0·001$.

home, work, or a second residence. Although subjects in Group B were significantly more likely than those in Group A to avoid drinking water directly from the tap, there was no significant difference between cohorts in the subset who drank neither tap nor filtered water: 30 (20%) in Group B versus 25 (16%) in Group A.

Tap water avoidance

Among those subjects responding as drinking no tap water at home, work, or second residence, the number who reported that they were consistent in consuming no tap water in other forms (e.g. ice) or in other locations is shown in Table 2. Nineteen subjects, 42% of those drinking no tap water or 12% of all subjects, in Group B, and 11 subjects, 46% of those drinking no tap water or 7% of all subjects, in Group A, reported they never consumed tap water at friends' homes, restaurants, or in ice cubes. Only one subject from each cohort, or < 1% of all subjects surveyed, reported they never drank tap water at or outside of home or work, nor used tap water for making ice, brushing their teeth or preparing foods that would be eaten without cooking.

The proportion of subjects who reported drinking no tap water at home, work, or second residence is stratified by demographic group in Table 3. Subjects in Group B were more likely to drink no tap water than those in Group A (31% *vs.* 18%, respectively, of all subjects; OR 2·09, 95% CI 1·23–3·54, $P = 0·006$) irrespective of gender, ethnicity, educational level, and among persons > 30 years of age. The difference in the percentage of subjects avoiding tap water in Group B relative to Group A was greatest among black subjects (42% *vs.* 11%, respectively, OR = 5·9, 95% CI 2·1–16·4, $P = 0·0008$) and persons > 50 years of age (46% *vs.* 7%, respectively, OR 10·9, 95% CI 1·8–66·4, $P = 0·009$).

Within each cohort, males were more likely to avoid tap water than females, and this was statistically significant within Group A (22% of males *vs.* 7% of

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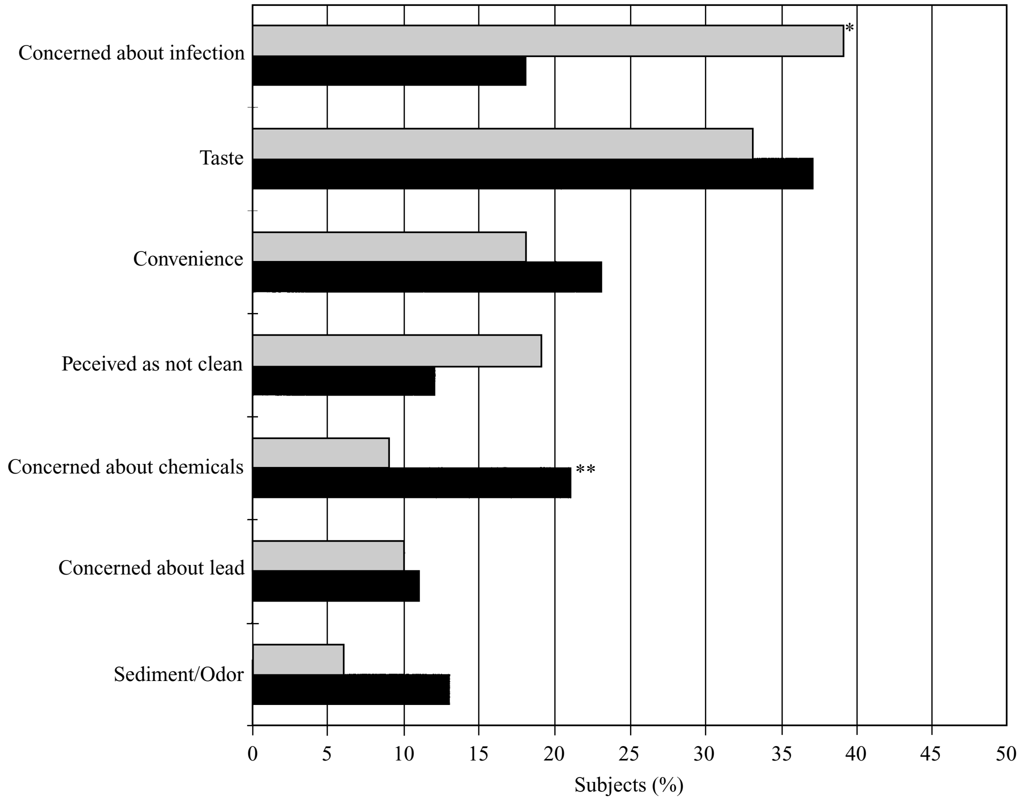

Fig. 2. Reasons for use of alternatives to tap water part or all of the time. ▨, Group A ($n = 141$); ■, Group B ($n = 131$). * $P = 0{\cdot}0002$; ** $P = 0{\cdot}01$.

females, OR 3·8, 95% CI 1·2–12·3, $P = 0{\cdot}03$). Within Group B, white subjects were significantly less likely to avoid tap water than persons of black, Hispanic or other ethnicity (20% *vs.* 44%, respectively, OR 0·31, 95% CI 0·15–0·63, $P = 0{\cdot}001$). Subjects in Group B aged 50 or older were significantly more likely than younger subjects to drink no tap water (46% *vs.* 24% respectively, OR 2·6, 95% CI 1·3–5·4, $P = 0{\cdot}009$). Educational level was not associated with tap water avoidance in either cohort.

Factors associated with tap water avoidance

The reasons given for choosing alternatives to tap water are shown in Figure 2. Significantly more subjects in Group A indicated concern about infection as a factor in their choice of drinking water source (39% *vs.* 18%, $P = 0{\cdot}0002$), while respondents in Group B were more likely to cite concerns about chemicals (21% *vs.* 9%, respectively, $P = 0{\cdot}01$). Subjects in Group A indicating concern for infection were significantly more likely to avoid drinking tap water at home or work than those not citing concern about infection: 19 of 55 (35%) versus 12 of 93 (11%), respectively (OR 4·1, 95% CI 1·9–9·0, $P = 0{\cdot}0004$). Among subjects using no tap water for drinking purposes at home or work, 19 (69%) subjects from Group A, but only 12 (26%) subjects from Group B, cited concern for infection as a motivating factor ($P = 0{\cdot}0003$).

Subjects who had received counselling on food or water consumption, or who had viewed or heard the September 1994 'Dateline NBC' programme on *Cryptosporidium* in water supplies, were no more likely than others to avoid drinking tap water. However, there was a surge in the number of subjects using boiled drinking water in Group A between June and November, 1994. Seventeen of 40 subjects (43%) who stated they used *any* boiled drinking water began doing so in this period, during which time there were a number of reports and editorials in the local media, in addition to the televized 'Dateline NBC' report. Nine of the 17 (53%) stated concern about waterborne infection. However, only 3 of 17 (18%) drank *no* water directly from the tap at home, work, or second residence, a rate no different than that in the Group A cohort as a whole. There was no similar surge in boiled water use in Group B, nor of filtered nor bottled water in either cohort.

Within Group A, there was no correlation between

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Table 4. *Number* (%) *of subjects who engaged in activities with potential to transmit* Cryptosporidium, *stratified by cohort and tap water consumption*

Exposure	Group A cohort			Group B cohort		
	All subjects $n = 160$ (%)	Subsets drinking > 50% tap water $n = 84$ (%)	Subsets drinking No tap water $n = 28$ (%)	All subjects $n = 153$ (%)	Subsets drinking > 50% tap water $n = 79$ (%)	Subsets drinking No tap water $n = 47$ (%)
Contact with animals						
Any	96 (60)	56 (67)	14 (50)	83 (54)	45 (57)	23 (49)
Visit to pet shop	68 (43)	39 (46)	12 (43)	51 (33)	28 (35)	14 (30)
Handling cat litter box	34 (21)†	23 (27)§	1 (4)§	7 (11)†	8 (10)	4 (9)
Visit to veterinarian's ofc	28 (18)	14 (17)	8 (29)	21 (14)	13 (17)	4 (9)
Puppy or kitten at home	25 (16)†	12 (14)	5 (18)	11 (7)†	5 (6)	4 (9)
Farm*	12 (8)†	6 (7)	3 (11)	25 (16)†	13 (17)	8 (17)
Petting zoo*	12 (8)	6 (7)	2 (7)	5 (3)	2 (3)	3 (6)
Dog pound	8 (5)	2 (2)	1 (4)	2 (1)	2 (3)	0
Dog/cat show	2 (1)	1 (1)	0	1 (1)	1 (1)	0
Swimming*						
In swimming pool	42 (26)	23 (27)	6 (21)	55 (36)	31 (39)	12 (26)
In lake or river	12 (8)	6 (7)	1 (4)	8 (5)	5 (6)	2 (4)
Travel to developing country*	24 (15)	12 (14)	7 (25)	28 (18)	13 (17)	11 (23)
Cared for person with diarrhoea*	19 (12)	10 (12)	1 (4)	13 (8)	5 (6)	2 (4)
Contact with person who has cryptosporidiosis*	14 (9)‡	5 (6)	4 (14)	2 (1)‡	1 (1)	0
Childen under 3 years old at home*	12 (8)	11 (13)	1 (4)	15 (10)	10 (13)	3 (6)
Faecal–oral sexual contact*	15 (9)‡	10 (12)	2 (7)	1 (1)‡	1 (1)	0
Consumption of lake, stream or river water*	5 (3)	1 (1)	0	3 (2)	1 (1)	0
Gardening	39 (24)	17 (20)	7 (25)	24 (16)	12 (15)	6 (13)
Camping	6 (4)	1 (1)	1 (4)	8 (5)	7 (9)	1 (2)
Consumption of unpasteurized dairy products	5 (3)	1 (1)	1 (4)	1 (1)	0	0
Consumption of unwashed fruits or vegetables	5 (3)	2 (2)	1 (4)	3 (2)	1 (1)	2 (4)
Subjects with one or more non-tap water exposure risks						
Recognized exposure risks	91 (57)	52 (62)	14 (50)	91 (60)	49 (62)	24 (51)
Recognized and potential exposure risks	125 (78)	67 (80)	20 (71)	116 (76)	61 (77)	32 (68)

* Recognized risk for transmission.
† $P \leqslant 0{\cdot}02$ between cohorts.
‡ $P \leqslant 0{\cdot}01$ between cohorts.
§ $P \leqslant 0{\cdot}01$ between subjects drinking and avoiding tap water.

CD_4 lymphocyte count, or having a history of opportunistic infection, and avoiding tap water consumption (data not shown).

Exposures other than municipal water

Rates of exposure to selected 'recognized' and 'potential' environmental sources of *Cryptosporidium* transmission, other than municipal water consumption, are presented in Table 4. Recognized risks are denoted by an asterisk. Group A and B cohorts were similar in the percentage of subjects with one or more non-tap water exposure risks: 78% of Group A and 76% of Group B had at least one *recognized or potential* exposure; 57% and 60% of each cohort, respectively, had at least one *recognized* exposure.

While the two cohorts had similar prevalences to most exposures, there were a few differences. Subjects in Group A were significantly more likely to have had

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contact with a person with cryptosporidiosis (OR 7·2, 95% CI 2·0–26·6, $P = 0{\cdot}003$), to have engaged in sexual activity involving oral–anal contact (OR 15·7, 95% CI 3·4–73·7, $P = 0{\cdot}0005$), to have handled a cat litter box (OR 2·2, 95% CI 1·2–4·0, $P = 0{\cdot}015$) or to have a puppy or kitten at home (OR 2·4, 95% CI 1·2–5·0, $P = 0{\cdot}02$). Subjects in Group B were more likely to have visited a farm (OR 2·4, 95% CI 1·2–4·9, $P = 0{\cdot}015$). These differences remained statistically significant in a multivariate analysis adjusting for the demographic composition of each cohort.

Future investigation of the risk of acquiring cryptosporidiosis from drinking municipal water could be confounded by other putative sources of exposure. In order to evaluate the potential for such confounding factors, we calculated whether subjects who consistently avoided drinking tap water were any more or less likely to engage in other activities that could expose them to *Cryptosporidium* than subjects who drank substantial amounts of tap water (Table 4). We defined tap water 'avoiders' as the subset of subjects who drank no tap water at home, work, or a second residence, and tap water 'users' as the subset who obtained at least half of their home drinking water directly from the tap. Conditional on these definitions, there were no significant differences in the prevalence of other exposures between tap water 'users' and 'avoiders' in Group B. Within Group A, only one statistically significant association was found: tap water 'avoiders' were significantly less likely than tap water 'users' to have changed a cat litter box in the 6 months prior to interview: 4% *vs.* 27% respectively (OR 0·10, 95% CI 0·02–0·55, $P = 0{\cdot}008$). There was no association between tap water consumption and total number of non-tap water risks per subject.

DISCUSSION

Demographics

The Group A and Group B cohorts differed significantly in gender, age distribution, and percentage of Hispanic subjects. However, the observed differences between cohorts in the prevalence of tap water avoidance and of non-tap water risk factors were independent of demographics, as determined by univariate and multivariate analysis.

The preponderance of males and persons aged 31–50 in Group A was representative of the practice base from which it was drawn, and is consistent with the continued significant proportion of homosexual males, and young-to-middle-age adults, in New York City's HIV-infected population. The high proportion of females in Group B derives from the predominantly female patient base of one practice from which subjects were recruited.

Study subjects were recruited from among individuals seeking outpatient medical care. These outpatients may have more medical illnesses or may be more health conscious relative to the population at large, which includes persons who do not routinely seek medical care. While we feel that our study population is a fairly broad representation of New York City residents, these issues must be considered in extrapolating our findings to the City population as a whole.

Drinking water

Both cohorts were heterogeneous with respect to the sources and treatment of water used for drinking. Substantial subsets, 18% of Group A subjects and 31% of Group B subjects, denied use of water directly from the tap for drinking purposes. However, isolation from exposure to tap water was nearly never absolute in our subjects, as many of those not drinking tap water at home or work did so when visiting friend's homes or restaurants, and all but one subject from each cohort had at least some exposure, as in brushing teeth or washing foods. In addition, this survey may not have captured other sources of exposure to municipal water such as showering or in foods or beverages prepared outside the home.

Though tap water avoidance may never be absolute, variation in the amount of water consumed from a tap versus other sources of drinking water indicates that an observational study designed to assess the quantity of water consumed from various sources could be useful in assessing the risk of acquiring cryptosporidiosis, and other waterborne infections, from drinking municipal tap water. Indeed, risk of infection has been shown to increase in step-wise fashion with progressively greater estimated tap water consumption in at least one outbreak of waterborne cryptosporidiosis [2, 22]. Quantification of the actual volume of municipal water consumed, not included in our questionnaire, would be optimal, but the accuracy in obtaining volume estimates could be questionable.

A significant proportion of subjects avoiding direct consumption of tap water in Group B, and to a lesser extent in Group A, *did* drink tap water after treatment with a point-of-use filter. As the effectiveness of home filtration systems in removing pathogens varies [18, 31], in many cases filtered water may have been equivalent to tap water in risk for *Cryptosporidium* transmission. Since most respondents could not at the time of interview specify the type of filtration system employed, we were not able to assess the contribution of ineffectively filtered water to exposure risk on an individual basis. However, there was a significant subset of subjects in each cohort who drank *neither* tap *nor* filtered water, and would therefore be relatively free from such exposure. If people who filter tap water at home are included in a study to assess the risk of cryptosporidiosis from drinking water, those persons with filters that effectively remove *Cryptosporidium* must be distinguished from those that do not. This would require comprehensive documentation of the types and models of point-of-use filters used. Even so, factors such as improper filter use could still be confounding.

Factors associated with tap water avoidance

An unexpected finding was that significantly more subjects avoided drinking tap water in Group B than in Group A. The difference between cohorts was most pronounced among black subjects and subjects over 50 years. The higher rate of tap water avoidance among blacks and persons over 50 in Group B was independent of gender or educational level attained and is unexplained.

Cryptosporidiosis poses a particularly great health risk to persons with AIDS, for whom infection can be chronic and fatal. Significantly more respondents in Group A cited concerns about infection risk as a reason for using alternatives to tap water, and these subjects were significantly more likely to avoid drinking tap water than those citing no concern about infection. In addition, subjects in Group A were more likely to boil their drinking water, consistent with an effort to limit exposure to waterborne pathogens. A surge in the use of boiled water within Group A occurred during a period of increased media coverage of the risk of waterborne cryptosporidiosis, suggesting that such programs may be influential in modifying behaviours in this population. However, among the new boiled water users, the percentage who consistently avoided tap water at all times was no different than among others in the cohort. As indicated by data derived from outbreak investigations, the protective effect of consuming safe water only part of the time may be limited [5, 31].

Males in Group A were significantly more likely to avoid tap water than females. It is possible that this reflects greater awareness and response to potential infection risks among the gay community, possibly through interaction with peers or support groups such as Gay Men's Health Crisis. However, there was no association within Group A between decreased CD_4 count, a history of opportunistic infection, nor a history of infection prevention counselling, and likelihood of avoiding tap water. Thus, awareness of more advanced immune compromise, and formal counselling on infection prevention, apparently had limited impact on tap water consumption.

Overall, there are indications in this survey that subjects in Group A were more concerned about waterborne infection than Group B subjects, and that this had some impact on their exposure to municipal water. However, for many of these subjects, the behavioural response was only a partial reduction in tap water consumption, and the rate of tap water avoidance in Group A was actually lower than that in Group B.

Exposures other than municipal water

This survey indicates that, in addition to municipal water consumption, exposure to other possible risks for cryptosporidiosis are common. The majority of subjects in both cohorts had at least one risk for exposure to *Cryptosporidium* other than tap water.

In Group A, there was a correlation between drinking tap water and only one of the many potential exposure risks queried: subjects drinking no tap water were significantly less likely to have changed a cat litter box in the 6 months prior to survey. This may be an indication that Group A subjects who are avoiding tap water are also following the widely publicized recommendation that HIV-positive individuals limit their contact with cats, which often carry the opportunistic pathogen *Toxoplasma gondii*, and which are also susceptible to *Cryptosporidium* infection [30].

Though there was no association between most of the exposure risks queried and municipal water consumption, it is possible that behaviours will change in response to concerns about infection risk, particularly with ongoing media attention to cryptosporidiosis. Non-tap water exposure risks could potentially confound any observational or interventional epidemiologic study of the relationship between municipal water consumption and cryptosporidiosis unless appropriate controls are incorporated.

Conclusions

This study characterizes potential exposure risks for *Cryptosporidium* among selected cohorts of New York City adults. Direct consumption of municipal water varied greatly among individuals in both groups, with distinct subsets using no tap water for drinking purposes at home or work. However, when other sources of water ingestion were assessed, absolute avoidance of tap water was rare. In addition, most subjects had other potential risks for exposure to *Cryptosporidium*.

The association between sporadic cryptosporidial infection and environmental exposures is poorly understood. Concerns have recently focused on low levels of *Cryptosporidium* oocysts in municipal water supplies in New York City as well as a number of other places; though no association with sporadic cryptosporidiosis has been made, costly measures to decrease contamination are under consideration [25, 26]. Public health experts agree that studies to investigate the association of cryptosporidiosis with exposures such as municipal water are needed; interventional studies and observational studies have been proposed [1, 17, 18]. The heterogeneity in municipal water consumption revealed in this study supports the feasibility of observational studies to investigate this association. The finding that potential non-municipal water exposures are common, and that at least one may correlate with degree of municipal water consumption, supports epidemiologic investigation of these risks themselves, as well as controlling for them in evaluating the risk from municipal water. Observational studies, such as those with case-control or cross sectional designs, could investigate multiple risks.

The finding of different tap water consumption patterns between the two cohorts, as well as between certain demographic groups in this study, suggests epidemiologic studies would also need to control for these patient characteristics.

Until the risks for sporadic cryptosporidiosis are better defined, broad preventive recommendations will be less effective than focusing on those exposures that appear to have the greatest risk. Immunocompromized patients, especially those with HIV infection, should be counselled that certain activities, such as handling young livestock, swimming in freshwater bodies or public pools, any human contact with potential faecal–oral exposure, and consumption of municipal water during a boil-water advisory or in regions with poor sanitation, are recognized risks [1, 2, 18]. The potential but unknown risk from other exposures, including municipal water consumption under normal circumstances, should be discussed, but providing specific recommendations is difficult and must be individualized.

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