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Use of Passive Surveillance Data to Study Temporal and Spatial Variation in the Incidence of Giardiasis and Cryptosporidiosis

SYNOPSIS

Objective. The goal of this study was to evaluate temporal and spatial variations in the reporting of cases of giardiasis and cryptosporidiosis to a passive surveillance system, and to assess the relationship of those variations to source of drinking water, adjusting for socioeconomic variables.

Methods. The authors analyzed temporal and spatial patterns for 4,058 cases of giardiasis and 230 cases of cryptosporidiosis reported to the Massachusetts Department of Public Health for 1993–1996. They linked each reported case to a database containing information on source of residential water supply and socioeconomic characteristics and evaluated the association between these factors and reporting rates using regression techniques.

Results. Reports of giardiasis and cryptosporidiosis were highest for the mixed unfiltered drinking water supply category. Reports of giardiasis were associated with income levels. Increases in reporting for both giardiasis and cryptosporidiosis were seen in summer to early fall. During a suspected outbreak of cryptosporidiosis in the city of Worcester in 1995, a significant increase in reported cases was also observed in the Boston metropolitan area. Following the suspected outbreak, weekly giardiasis rates increased slightly in Worcester and the Boston metropolitan area, while reporting of cryptosporidiosis increased dramatically.

Conclusions. Consistently collected passive surveillance data have the potential to provide valuable information on the temporal variation of disease incidence as well as geographic factors. However, passive surveillance data, particularly in the initial period of surveillance, may be highly sensitive to patterns of diagnosis and reporting and should be interpreted with caution.

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Since the mid-1980s, many states have initiated surveillance for giardiasis and cryptosporidiosis, requiring both laboratories and physicians to report all laboratory-confirmed cases of these diseases to local or state health departments. The main reason for surveillance of these diseases is the well-established potential for waterborne disease outbreaks associated with the protozoan pathogens *Giardia lamblia*[1,2] and *Cryptosporidium parvum*.[3] Surveillance systems are also useful for identifying cases of waterborne diseases, for detecting outbreaks, and for providing insight into risk factors.

While consistently collected surveillance data have the potential to provide valuable information on temporal patterns of disease incidence and on geographic variations, they may also have some limitations. It is intuitively obvious that incidence rates estimated using surveillance data can be skewed by an outbreak. It is also plausible that minor changes in physician testing practices can dramatically alter the number of reported cases for rarely diagnosed diseases such as cryptosporidiosis.[4,5] Unfortunately, very little is known about changes in reporting following outbreaks in either newly established or mature surveillance systems.

We used the information collected by the Massachusetts surveillance program for the years 1993–1996 to describe temporal and spatial variations in reported cases of giardiasis and cryptosporidiosis. We also investigated how these variations might be linked to water supply, after adjustment for socioeconomic characteristics that could have directly or indirectly influenced exposure or reporting.

In Massachusetts, giardiasis was made reportable in 1985, while cryptosporidiosis was made reportable in 1993, allowing us to contrast a more mature system with a newly established one. Furthermore, in the summer to early fall of 1995 one of the most populated cities in the state, Worcester, experienced a substantial surge in reported cases of cryptosporidiosis and an increase in testing for the disease.[6] This provided us the opportunity to evaluate the effects of an apparent outbreak of a rarely diagnosed disease on its reporting.

METHODS

We reviewed data on laboratory-confirmed cases of giardiasis and cryptosporidiosis reported to the Massachusetts Department of Public Health (MDPH) from January 1, 1993, through December 31, 1996. The dataset contained information on age, sex, Zip Code of residence, and date of disease onset for each reported case.

As part of the descriptive analysis, we plotted age distribution using the optimal, data-determined histogram bar width of two years. Each bar in the histogram represents the total number of cases in each age group, starting with the 0–2 age group.

Analysis of temporal variation. An analysis of temporal variation typically includes evaluations of annual trends, seasonal variations, and the effect of the day of the week, based on daily time series of reported cases. To examine temporal patterns, we created time series of daily counts of cases for both giardiasis and cryptosporidiosis for two age groups (children ≤18 years old and adults >18 years old). We used Pearson correlation coefficients to evaluate overall similarities between the time series for the two diseases.

In a more detailed analysis, we estimated the relative effect of each temporal factor (year, month, and day of the week) on daily reporting using a generalized linear model with the Poisson distribution for an outcome and a set of dummy variables for these temporal factors. This model provides estimates of relative risk and their 95% confidence intervals (CIs) that reflect the relative increase in the number of reported cases for a given category compared with the corresponding reference category. Following customary practice,[7] we chose the category with the smallest number of cases as the reference category; these were 1993, December, and Sunday.

To evaluate the consistency of temporal patterns, we applied an approach based on plotting cumulative counts of daily reported cases against the time in days. This approach is efficient in demonstrating the effects of seasonal fluctuations and outbreaks on the temporal properties of a time series.[8] For a disease with a constant incidence rate, this plot would be close to a straight line from the lower left to upper right corner of the graph. Regular, periodic departures from this straight line may reflect seasonal fluctuations. Outbreaks would be reflected by sudden changes in local slopes.

Due to the potential effect of the Worcester outbreak on reporting, we examined consistency in temporal reporting patterns for the two largest cities in Massachusetts: Boston and Worcester. We abstracted all cases from the city of Worcester and the Boston metropolitan area, based on Zip Code of residence, and created four time series of cumulative daily counts. Then we plotted cumulative daily counts for the two diseases and two locations against time in days, and examined the resulting four plots for departures that reflect seasonal fluctuations and outbreaks.

Analysis of changes associated with a suspected outbreak. To evaluate changes in reporting associated with a suspected outbreak in Worcester, we used estimated weekly incidence rates. We first converted the time series of daily counts to time series of weekly counts by calculating the numbers of cases for seven-consecutive-day windows. We then estimated the crude weekly rates of disease reports for the two geographic locations, the Boston metropolitan area and Worcester, by dividing counts for each week by population estimates obtained from 1990 Census data. We compared these two time series of weekly rates with similarly created time series of statewide estimates of weekly rates.

We estimated the average crude rates for both diseases for the Boston metropolitan area, Worcester, and statewide, and determined mean and ranges of weekly counts for three time periods: before, during, and after the Worcester outbreak. The time period for the Worcester outbreak was July 24, 1995, to October 1, 1995.[6]

Analysis of variation by water supply category. To evaluate spatial variation, we linked each reported case to a database that included information on residential water supply and socioeconomic characteristics. We created this database using data from the *1990 Census of Population and Housing,*[9] which provided information on socioeconomic characteristics (age distribution, number of housing units, per capita income, distribution of educational attainment for individuals >15 years of age) and frequencies of types of water supply for each Zip Code in the state, and 1995 data provided by the Massachusetts Department of Environmental Protection (MDEP) on the type of source water received and use of filtration for all public water supplies for each town in the state.

First, for each ZIP Code we categorized the water supply as "private" or "public." In the 1990 Census data, water supplies that served fewer than five housing units were considered private. Using these data, we calculated the percentages of housing units served by private and public water supplies for each ZIP Code. If more than 50% of the residences in a given ZIP Code were served by private wells, we categorized the water source as private groundwater (PG). All other ZIP Codes were categorized as having public water supplies.

In the DEP database, each town water supply was classified, first, by the type of source water received (ground, surface, or mixed) and second, by whether filtration was used (filtered, unfiltered, or mixed). Hence, there were nine possible public water supply categories: surface unfiltered (SU), surface filtered (SF), surface mixed (SM), ground unfiltered (GU), ground filtered (GF), ground mixed (GM), mixed unfiltered (MU), mixed filtered (MF), mixed mixed (MM). If more than 75% of residents in a given ZIP Code were served by one type of water supply, we classified the ZIP Code as belonging to that type; otherwise it was classified into one of the mixed categories (SM, GM, MU, MF, or MM) as appropriate. In all but one of the unmixed categories, a large majority of housing units were served by one type of water supply system: GU (90% of housing units), PG (84%), SU (95%), and SF (96%).

Next, we estimated crude rates of disease for two age groups (≤18 and >18 years old) and for the state's five major water supply categories: PG, SU, SF, GU, and MU.

Finally, we evaluated the associations between water supply category and rates of giardiasis and cryptosporidiosis at the Zip Code–area level using a generalized linear model. We calculated the total number of reported cases of each disease over the four-year period for each ZIP Code. Using these counts we estimated annual crude incidence rates per million population for the five major water supply categories. Based on the model results, we estimated the relative risk for each disease associated with each water supply category, adjusting for ZIP code–specific socioeconomic characteristics: per capita income and weighted average years of education of people ≥age 15, calculated from Census data.

Combined analysis of spatial and temporal variation. To perform a combined analysis of spatial and temporal variations, we used daily incidence of giardiasis for three water supply categories (SU, SF, and GU), a subset for which we had sufficient data for the simultaneous analysis. We evaluated temporal fluctuations in the estimated rate of giardiasis for the two age groups and the three major water supply categories using time series of daily rates of giardiasis per 1,000,000 population. We constructed annual cycle curves by superimposing four years of time series and plotted the resulting annual cycle curve smoothed by the LOWESS procedure[10] for each water supply category.

RESULTS

MDPH received reports of 4,058 confirmed cases of giardiasis and 230 confirmed cases of cryptosporidiosis in 1993–1996. The age distributions for reported cases for both diseases were bimodal (Figure 1), with the higher peak among young children (<6 years) and with a second peak among young adults (30–34 years old). The peak among young adults was more pronounced for cryptosporidiosis.

For giardiasis, the male-to-female ratio was highest (1.3) among young children <6 years old, declining to 0.9 in adults >18 years of age (not shown). For cryptosporidiosis, the male-to-female ratio was constant at 1.4 for all ages.

Temporal variations. Total monthly counts over the four-year period for both diseases are shown in Figure 2. Both had strong seasonal cycles, with a trough in the late winter and spring and a peak in the late summer and early fall. Although reports of giardiasis and cryptosporidiosis had similar temporal characteristics, with a moderate correlation between daily counts for the two diseases over the four-year time period of 0.23 (P <0.001), the seasonality was more pronounced for cryptosporidiosis, with a narrower (August through October) and steeper peak than that for giardiasis.

Using a generalized linear model for a time series of daily counts, we evaluated the relative magnitude of temporal fluctuations in reported disease rates for children and adults. The relative risk of an increase in reported cases associated with each month is shown in Table 1. For cryptosporidiosis, the seasonal cycle was more pronounced in children, with the highest increase in reported cases in August. We also observed a significant positive trend in annual reporting of cryptosporidiosis even after adjustment for seasonal fluctuations (7 cases in 1993, 10 in 1994, 130 in 1995, and 83 in 1996), but no such trend in giardiasis (1,077 cases in 1993, 991

Figure 1. Age distributions of reported cases of giardiasis and cryptosporidiosis, Massachusetts, 1993–1996

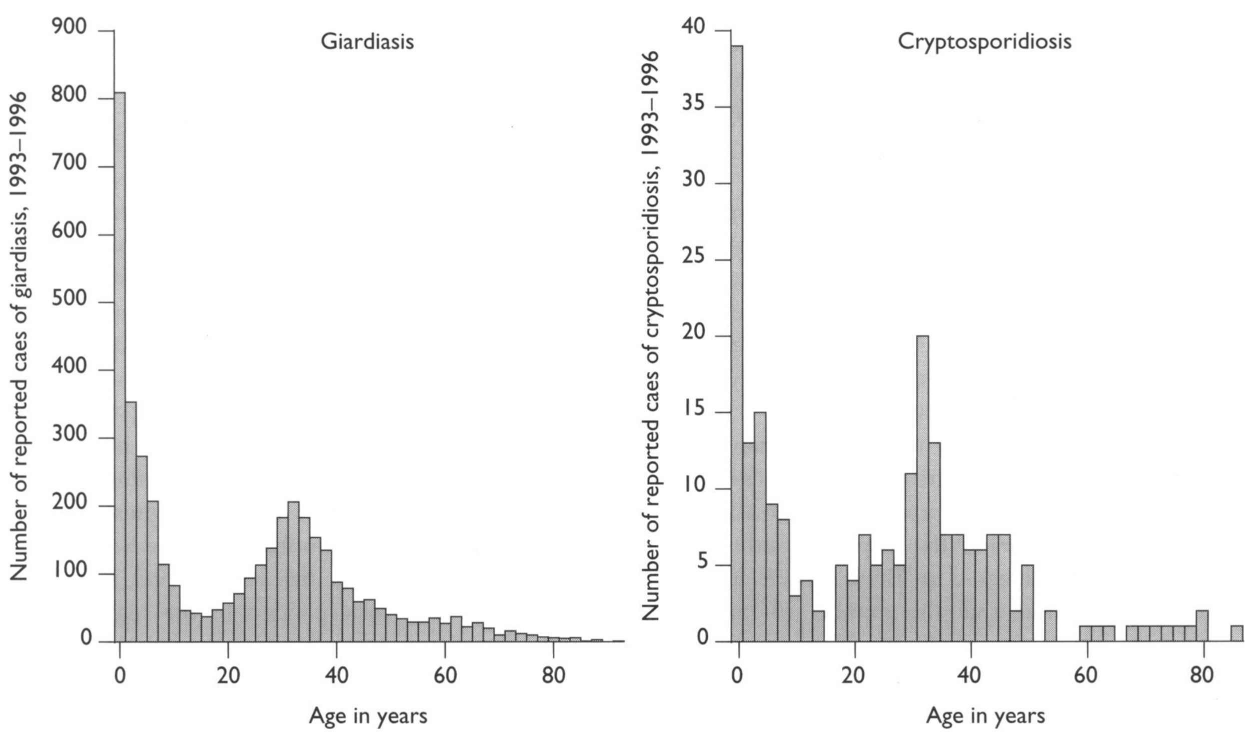
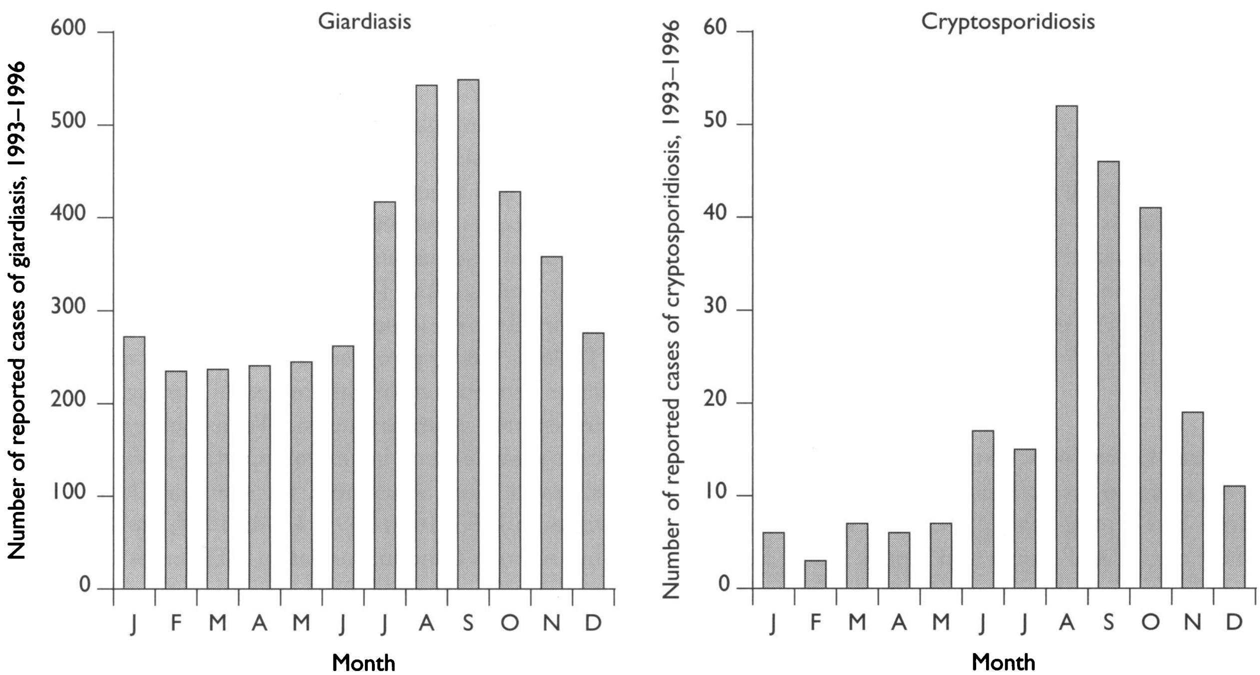


Figure 2. Total monthly counts of giardiasis and cryptosporidiosis for the four-year study period



in 1994, 1,018 in 1995, and 977 in 1996). Although we did not observe a strong effect of day of the week, for both diseases report rates were higher for Monday than for any other day of the week.

Cumulative disease incidence. The cumulative incidences of reported cases of cryptosporidiosis and giardiasis as identified by the MDPH's passive surveillance system for two areas, the Boston metropolitan area and Worcester, are shown in Figure 3. The plots reflect the cumulative numbers of cases calculated on a daily basis and plotted against the time in days.

Giardiasis reporting was far more stable than cryptosporidiosis reporting in both areas. A sharp increase in the cumulative incidence of cryptosporidiosis in Worcester was observed at the time of the suspected outbreak in July–September 1995 (marked as "Burst A" in Figure 3). It is interesting to note that the number of reported cases of cryptosporidiosis also increased in the Boston metropolitan area (marked as "Burst B") shortly after this suspected outbreak was identified in Worcester. An additional sharp increase in the cumulative incidence of cryptosporidiosis in Worcester was observed about a year later (marked as "Burst C"), during a period of active surveillance (laboratory- and nursing home–based) conducted by MDPH.

Effect of the suspected outbreak. To evaluate the effect of the suspected outbreak on reporting, we calculated the total counts of giardiasis and cryptosporidiosis cases for the Boston metropolitan area and Worcester for seven-consecutive-day intervals. The mean number of reported cases per week along with the range for three time periods—before, during, and after the Worcester outbreak—are shown in Table 2. During the week of August 31, 1995, to September 6, 1995, nine cases of cryptosporidiosis were reported in the Boston metropolitan area. This was the week with the highest number of reported cases of cryptosporidiosis for the Boston metropolitan area during the entire study period, and the timing of this event corresponded to the highest weekly count of reported cryptosporidiosis cases in Worcester (four reported cases).

We evaluated weekly rates of case reports of cryptosporidiosis and giardiasis for the weeks before, during, and after the suspected Worcester outbreak of cryptosporidiosis. Weekly rates for the Boston metropolitan area, Worcester, and statewide are shown in Table 2. During the suspected outbreak, weekly rates of reported giardiasis increased slightly in the Boston metropolitan area and more, though not significantly more, in Worcester. The reporting of cryptosporidiosis, however, increased drastically in comparison to the weeks before the outbreak: by 20-fold in the Boston metropolitan area and 50-fold in Worcester. During the suspected outbreak of cryptosporidiosis in Worcester, a significant increase in reported cryptosporidiosis was also observed in the Boston metropolitan area, with the average number of reported cases per week exceeding the pre-outbreak level by 50-fold.

Analysis of spatial variation and associations with water supply. Of the 475 ZIP Codes in Eastern Massachusetts, 111 (23%) had at least one reported case of cryptosporidiosis and 403 (85%) had at least one reported cases of giardiasis for the four-year study period.

The total populations served by Zip Codes in each of five major water supply categories—PG, SU, SF, GU, and MU—as well as the number of reported cases and crude incidence rates of reported cases per 1,000,000 population per year are shown in Table 3. Among those communities with public drinking water supplies, giardiasis rates were highest for the MU and SU categories, followed by the GU and SF categories. Cryptosporidiosis followed a similar pattern.

The MU category had the highest rate among water supply categories for both diseases. For cryptosporidiosis, and to a lesser extent for giardiasis, this appears to have been driven by the suspected Worcester outbreak. If excess cases reported during this suspected outbreak are excluded (by replacing the numbers of cases reported in 1995 by the average number of cases reported for the remaining three years), the rate of giardiasis for this water supply category becomes 214.8 per million population and the rate for cryptosporidiosis becomes 8.44 per million population. It is interesting to note that in all water supply categories, for each case of reported cryptosporidiosis we observed from 14 to 20 cases of reported giardiasis, but in two water supply categories we observed extremely disproportionate rates—68 cases of giardiasis for each case of cryptosporidiosis in the SF

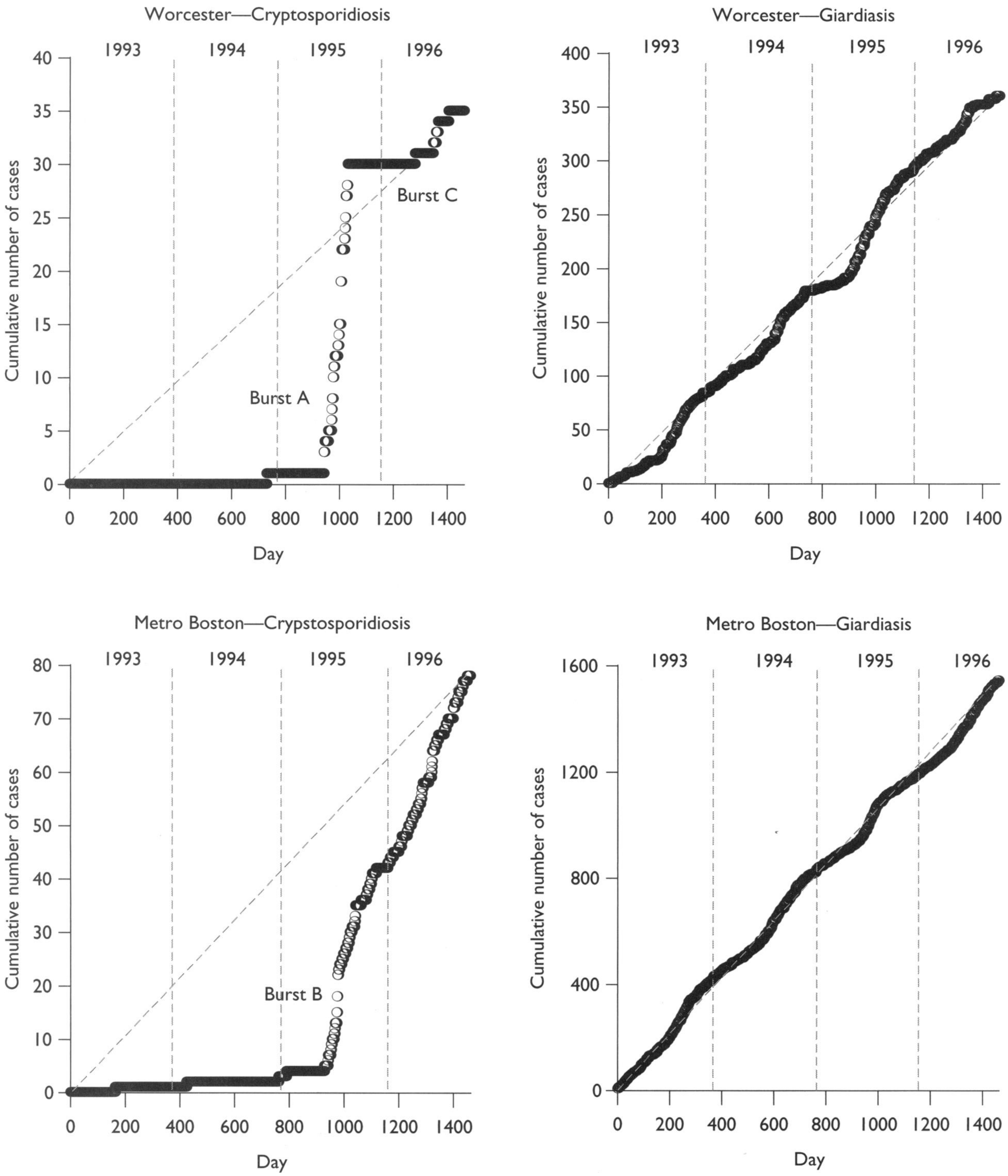
Table 1. Relative risk of incidence of giardiasis and cryptosporidiosis in children and adults, by month, Massachusetts, 1993–1996

	Giardiasis				Cryptosporidiosis			
	Children (≤18 years old)		Adults (>18 years old)		Children (≤18 years old)		Adults (>18 years old)	
Month	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
January	1.28	1.02, 1.61	0.72	0.56, 0.92	0.67	0.11, 3.98	0.50	0.15, 1.66
February	1.12	0.88, 1.42	0.77	0.60, 0.99	0.37	0.04, 3.47	0.27	0.06, 1.28
March	0.96	0.75, 1.23	0.76	0.60, 0.98	0.33	0.04, 3.16	0.75	0.26, 2.16
April	1.03	0.81, 1.30	0.79	0.62, 1.01	0.34	0.04, 3.27	0.65	0.21, 1.97
May	0.83	0.64, 1.06	0.94	0.75, 1.19	0.67	0.11, 3.98	0.63	0.20, 1.91
June	0.85	0.66, 1.09	1.11	0.88, 1.39	2.41	0.62, 9.32	1.29	0.51, 3.27
July	1.39	1.12, 1.74	1.62	1.31, 1.99	2.67	0.71, 10.05	0.87	0.32, 2.41
August	1.91	1.55, 2.35	2.02	1.66, 2.47	9.67	2.95, 31.71	2.88	1.29, 6.43
September	2.03	1.65, 2.50	2.08	1.70, 2.54	6.89	2.05, 23.17	3.36	1.52, 7.42
October	1.46	1.17, 1.82	1.62	1.32, 2.00	5.00	1.45, 17.26	3.25	1.47, 7.18
November	1.30	1.04, 1.63	1.38	1.11, 1.71	1.38	0.31, 6.15	1.94	0.82, 4.57
December	1.00		1.00		1.00		1.00	

RR = relative risk, compared to December

CI = confidence interval

Figure 3. Cumulative incidence of cryptosporidiosis and giardiasis in the Boston metropolitan area and Worcester for the four-year study period



category, and an 8:1 ratio in the MU category—which might have accentuated the effect of filtration.

The associations between water supply categories and rates of giardiasis and cryptosporidiosis were also evaluated using a regression model that included socioeconomic characteristics (per capita income and adults' average years of education). The estimates of relative risk associated with water supply category, with PG as the reference category, are shown in Table 4. The highest rates of both giardiasis and cryptosporidiosis were associated with residence in communities in the MU category. ZIP Code areas with per capita incomes above the state mean income of $17,760 had higher rates of giardiasis than areas with per capita incomes below the mean (RR = 1.70; 95% CI 1.67, 1.73). The cryptosporidiosis rate did not show any relationship with either of the two socioeconomic characteristics.

Combined analysis of temporal and geographic variation in reported cases of giardiasis. To examine subtle differences in temporal and spatial variability, we evaluated temporal fluctuations in daily rates of reported giardiasis per 1,000,000 population for three categories of water supplies—SU, SF, and GU—and for two age subgroups (≤18 and >18 years old). Smoothed annual cycle curves of giardiasis rates are shown in Figure 4 for children and Figure 5 for adults. The three water supply categories showed similar temporal patterns, with increased rates from July to September in both age groups. For children, the SU category had the highest mean daily rate of giardiasis (1.27±1.21 for SU, 0.77±0.87 for GU, and 0.78±1.01 for SF). For adults, mean daily rates of giardiasis were very similar for the three water supply categories (0.33±0.32 for SU, 0.31±0.32 for GU, and 0.26±0.33 for SF).

DISCUSSION

This analysis of data from the Massachusetts surveillance systems for giardiasis and cryptosporidiosis identifies several important factors that may be associated with incidence rates. Our analysis identified source of drinking water (as a proxy for probability of exposure), income (perhaps as a proxy for access, utilization, and quality of health care), and seasonal variations (which may represent a broad array of environmental factors) as being significant. Consistently collected passive surveillance data can be valuable for the detailed analysis of temporal properties of the incidence of these diseases, which are often waterborne. However, passive surveillance data may be highly sensitive to inconsistent patterns of physician or laboratory diagnosis, and thus

Table 2. Estimated weekly rates of reported cases of cryptosporidiosis and giardiasis in the Boston metropolitan area, Worcester, and statewide for three time periods: before (134 weeks of observations), during (10 weeks) and after (65 weeks) the suspected Worcester outbreak of July 24–October 1, 1995

	Giardiasis			*Cryptosporidiosis*		
Geographic area	*Before*	*During*	*After*	*Before*	*During*	*After*
Boston metropolitan area						
Estimated crude rate per million population	3.02	6.75	3.56	0.02	1.05	0.41
Mean number of cases reported per week	6.05	13.50	7.13	0.04	2.10	0.82
Range	1–19	7–19	1–21	0–5	0–9	0–7
Worcester						
Estimated crude rate	2.45	9.90	5.33	0.02	3.38	1.21
Mean	1.02	4.10	2.21	0.01	1.40	0.50
Range	0–1	0–9	0–4	0–1	0–4	0–4
Massachusetts						
Estimated crude rate	3.07	5.71	3.23	0.04	1.18	0.34
Mean	18.5	34.33	19.44	0.23	7.11	2.06
Range	5–48	27–47	7–41	0–2	0–18	0–10

Table 3. Population served, number of reported cases, and annual crude incidence rate estimates per 1,000,000 population for giardiasis and cryptosporidiosis, by water supply category, Massachusetts, 1993–1996

			Giardiasis		Cryptosporidiosis	
Water supply category	*Number of ZIP Codes*	*Population served*	*Number of reported cases*	*Annual rate per 1,000,000 population*	*Number of reported cases*	*Annual rate per 1,000,000 population*
PG	93	276,992	155	139.9	11	9.9
SU	91	2,001,377	1543	192.7	78	9.7
SF	52	1,065,121	608	142.7	9	2.1
GU	179	1,664,845	1031	154.8	62	9.3
MU	25	414,286	378	228.1	49	29.6

PG = private groundwater
SU = surface unfiltered
SF = surface filtered
GU = ground unfiltered
MU = mixed unfiltered

reporting should be interpreted with caution. Our findings are consistent with the suggestion that the rate of reporting is heavily influenced by events affecting clinical diagnostic suspicion and case ascertainment, particularly for a disease such a cryptosporidiosis, which often requires a specific request for laboratory testing. Although we detected an overall upward trend in reporting for cryptosporidiosis, we also found dramatic increases in the number of reported cases in two urban areas during an apparent epidemic in only one of these two areas. Reported disease outbreaks and media attention may be expected to increase the reporting of identified cases of a disease. In fact, during the well-documented outbreak of cryptosporidiosis in Milwaukee in 1993, once the pathogen was recognized, laboratory testing for cryptosporidiosis increased by a factor of 100.[3]

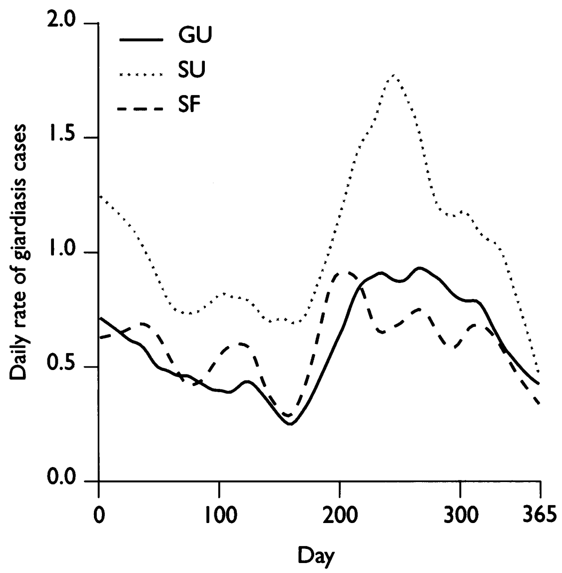
Table 4. Relative risk of incidence of giardiasis and cryptosporidiosis, by water supply category, adjusted for per capita income, Massachusetts, 1993–1996

	Giardiasis		Cryptosporidiosis	
Water supply category	*RR*	*95% CI*	*RR*	*95% CI*
PG	1.00		1.00	
SU	1.03	1.02, 1.03	0.97	0.94, 1.00
SF	0.95	0.94, 0.95	0.57	0.53, 0.60
GU	1.01	1.01, 1.02	0.95	0.92, 0.97
MU	1.36	1.34, 1.37	1.62	1.54, 1.70

RR = relative risk, compared to private groundwater (PG)
CI = confidence interval
PG = private groundwater
SU = surface unfiltered
SF = surface filtered
GU = ground unfiltered
MU = mixed unfiltered

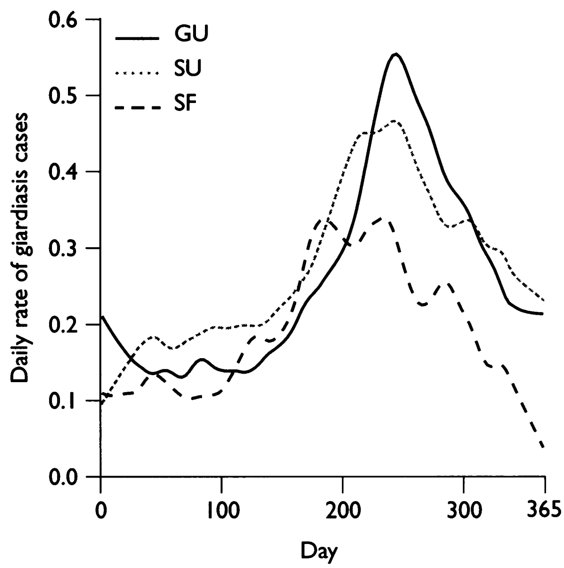
The seasonal variation seen in our data is consistent with that reported elsewhere. Reported cases increased in the late summer and fall by factors of up to 2.1 for giardiasis and 10 for cryptosporidiosis, compared with December. For cryptosporidiosis, the fall peak was narrower (August–October) than that for giardiasis (July–November) in both age groups. A similar surveillance program in Oregon identified seasonal peaks in cryptosporidiosis in the spring, summer, and early autumn months.[11] Studies in Germany,[12] the United Kingdom,[13] and Spain[14,15] found simi-

Figure 4. Seasonal fluctuations in daily rates of giardiasis among children ≤18 years old for three water supply categories: smoothed annual cycle curves



GU = ground unfiltered
SU = surface unfiltered
SF = surface filtered

Figure 5. Seasonal fluctuations in daily rates of giardiasis among adults >18 years old for three water supply categories: smoothed annual cycle curves



GU = ground unfiltered
SU = surface unfiltered
SF = surface filtered

lar peaks to those we observed, under similar climatic conditions. A study of the results of obligatory testing of all fecal samples submitted to the Massachusetts General Hospital laboratories in 1985 (which can be viewed as a short-term active surveillance effort for cryptosporidiosis) reported fall seasonality and an age distribution for cryptosporidiosis similar to those observed in the current study.[16]

Other surveillance systems have found parallel results for giardiasis. The seasonality that we found for giardiasis was consistent with the results of an analysis of data from Vermont's laboratory-based active surveillance system[17] and findings of a case-control study in New Hampshire,[18] where the occurrence of laboratory-confirmed, non-outbreak-related symptomatic cases peaked during the months of July through October. In Wisconsin, where *Giardia lamblia* infection became reportable in 1981, passive surveillance has shown a similar pattern, with an increased rate of giardiasis in the late summer through early fall.[19]

Seasonal variation in the incidence of an infectious disease reflects some seasonal change in the environment, in the pathogen, or in human behavior that increases the quantity of viable pathogens in the environment, changes the viability of individual pathogen cysts, or increases the probability of exposure of the human host to the pathogen. For example, warm weather activities such as camping, hiking, and swimming tend to increase exposure to recreational water sources, and thus to waterborne pathogens, during the late spring through mid-fall months.

The present findings show that the reported number of cases of both diseases varied with the type of water supply. The incidences of reported cases of both diseases were significantly higher in areas served by public supplies of filtered surface water than in areas served by unfiltered mixed water supplies and private wells. Similarly, the incidence of reported cases of giardiasis was higher in the areas served by public supplies of unfiltered surface and unfiltered groundwater than in the areas served by private wells.

A study in Vermont[17] also found that the rate of giardiasis was higher in areas served by unfiltered surface water supplies than by filtered water supplies. Our combined temporal-spatial analysis revealed that, although seasonal fluctuation in giardiasis had a similar pattern in adults across water supply categories, the magnitude of increase in children varied across water supply categories. We hypothesized that if the type of water supply plays an important role in the incidence of giardiasis, seasonal variation would be more closely linked to water supply among children than adults because: (*a*) children do not commute or travel from home as much as adults; (*b*) children can be more sensitive to increased cyst infectivity observed in fall[20]; and (*c*) children are less likely to have pre-existing immunity and, therefore, would tend to have relatively more symptomatic disease than adults.

Although it is plausible that the type of water supply is related to the incidence of giardiasis, we cannot rule out reporting bias or the effect of confounders that were not fully considered.

Our attempt to adjust for the effect of socioeconomic characteristics supports the assertion that per capita income influenced the reporting rate for giardiasis. The higher rate of reported giardiasis in higher-income households reflects an association between income and incidence, ascertainment, or both. We suspect that it reflects a greater likelihood of seeking medical care for diarrheal illnesses and a greater likelihood of being tested for giardiasis by medical providers, rather than a greater risk of exposure to the parasite. However, our data do not allow us to speculate any further.

Geographic variation in reported cases may also partly reflect differences in practice and diagnostic patterns on the part of physicians and laboratories. The potential for symptoms of giardiasis to persist far longer than symptoms of cryptosporidiosis in immunocompetent hosts increases the likelihood that patients will seek medical help and physicians will seek and obtain a specific diagnosis. However, the findings of a study by Roberts et al. suggest that many physicians do not commonly order specific tests for *Cryptosporidium* oocysts and many are unaware that these tests are not included in the standard order to examine stools for ova and parasites at most laboratories.[4] In the absence of effective therapy, there is limited incentive for physicians to order these specific tests or for laboratories to include them in standard testing procedures. The Centers for Diseases Control and Prevention (CDC) estimates that only 12 out of 250,000 patients would have been tested and diagnosed by physicians before *C. parvum* was identified as the cause of the 1993 outbreak of cryptosporidiosis in Milwaukee.[3,5]

On other hand, the low rate of testing for *Cryptosporidium* means that minor changes in physician testing practice can dramatically alter the number of reported cases. In response to a suspected outbreak of cryptosporidiosis in Worcester in 1995, the number of tests ordered for *Cryptosporidium* in one month increased by a factor of five.[6] Although a CDC investigation could not identify a single source as a cause of this outbreak, the rate of reporting for cryptosporidiosis in the state exhibited a significant upward trend after this suspected outbreak. Such an upward trend can be expected for a newly established surveillance system. In fact, similar trends were noted in Wisconsin after the initiation of surveillance for giardiasis.[17]

One can suggest that data from a newly established passive surveillance system, particularly for a disease for which testing is frequently not performed, will tend to reflect practice patterns rather than disease incidence. If we assume that once a system is well established, a particular physician's decision to test for a disease such as cryptosporidiosis is based on a particular constellation of signs and symptoms and the protocol of the laboratory he or she uses, then the fraction of cases detected by that physician should remain relatively stable over time. (This assumption underlies the use of passive surveillance data for outbreak detection.) If this is the case, then seasonal variation in reported cases should reflect the actual seasonal variation in disease incidence, and geographical variations should reflect the link to potential risk factors.

Our analysis identified important factors to be considered in the evaluation of reporting data for cryptosporidiosis and giardiasis, particularly in the early stages of development of a surveillance system. Passive surveillance data can potentially provide valuable information on temporal variations in disease incidence as well as geographic factors that influence these variations.

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