Epidemiological and clinical description of the top three reportable parasitic diseases in a Canadian community

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SUMMARY

This study provides a comprehensive epidemio-clinical picture of sporadic, domestically acquired
cases of amoebiasis, cryptosporidiosis and giardiasis in one Canadian community based on
patient symptom, outcome and exposure data from an enhanced surveillance system. It yields
valuable data for estimating the burden of those diseases including the proportion of bloody
diarrhoea, hospitalization, and disease duration. Age differences were observed by incidence rate
and for some clinical information and exposures to risk factors. For each of the three diseases,
the animal/environment-to-person route was the most common possible main transmission route
according to the exposure reported, whereas the person-to-person route was the least common.
Exposure was higher for the 10–24 years age group of giardiasis cases for swimming in
recreational waters (79%) and attending a barbeque (50%). Therefore, comparisons between
groups of cases or extrapolation of results when estimating the burden of illness should be
adjusted for age.

Key words: *Cryptosporidium*, gastroenteritis, giardiasis, parasitic disease epidemiology and control,
surveillance.

INTRODUCTION

Enteric parasitic infections like giardiasis and crypto-
sporidiosis continue to contribute to the overall bur-
den of disease in countries around the world [1, 2].
Parasitic infections share some characteristics with
other bacterial and viral gastrointestinal illnesses;
they are transmitted via the faecal–oral route,
through food, water and person-to-person trans-
mission, they are typically mild disorders, and their
incidence is largely underestimated as a result. Some
of these infections are zoonotic and include wildlife
and domestic animals as reservoirs.

Quantifying the economic and public health burden
of gastrointestinal illnesses in Canada continues to be
advocated, as governments prioritize prevention and
control measures to reduce the incidence and long-
term health and economic consequences from these

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infections [3, 4]. Specific parameters are required in models used to quantitatively assess the burden of disease, such as the severity of symptoms (e.g. bloody or non-bloody diarrhoea) to capture the frequency of under-reporting, as well as specific outcomes by disease (e.g. disease duration, hospitalization, death, sequelae) to estimate the economic impact from enteric disease and guide prevention and control measures [5, 6].

In Canada, microparasitic gastrointestinal diseases are relatively common with an overall incidence rate in 2004 of 13·1 and 1·85 reported cases/100 000 person-years for giardiasis and cryptosporidiosis, respectively [7]. Some cases reported to the health authorities in Canada are infected outside the country, between 25% and 63%, depending on the pathogen and study design [8, 9]. Both diseases are zoonotic involving mainly waterborne transmission from food animal reservoirs, and their epidemiology has been extensively studied to better understand public health risks from water and animal production [10, 11]. In contrast, the demographics and clinical course of the cases have been insufficiently described [12], and there is a lack of information available on disease severity, duration and exposures to common risk factors in the literature to inform burden-of-disease model development. As a result, recent Canadian efforts to estimate the burden of cryptosporidiosis or giardiasis in Canada have been based mostly on non-Canadian data [13, 14]. This is a recognized data gap.

This study describes the clinical and epidemiological characteristics of domestically acquired cases of the most common reportable parasitic enteric diseases in an Ontario community, from a burden-of-illness perspective. Data were collected from an integrated surveillance system of reportable parasitic enteric disease (C-EnterNet) to quantify the incidence of domestically acquired cases, to describe the demographic and clinical characteristics of these cases, and to assess the frequency of exposure to various potential sources of the pathogens.

MATERIAL AND METHODS

Population under study and time-frame

Data for this retrospective observational study were obtained from the National Integrated Enteric Pathogen Surveillance program, C-EnterNet [15]. More specifically, they came from one C-EnterNet sentinel site, the Region of Waterloo (ROW), Ontario where about 500 000 people reside in three cities and four rural townships in this area (http://maps.region. waterloo.on.ca/locator/locator.htm). The study period spanned the time period from June 2005 to May 2009, inclusive.

Surveillance data collection

C-EnterNet focuses on illnesses caused by enteric pathogens that are reportable in Canada, including amoebiasis, cryptosporidiosis, cyclosporiasis, and giardiasis. C-EnterNet builds on the existing laboratory-based surveillance system in Canada for reportable illnesses, which involves the mandatory reporting of all confirmed notifiable diseases by the screening clinical laboratories to the local public health authority. In ROW, this system was enhanced by implementing a systematic follow-up of each reported case by a public health inspector using a standardized questionnaire (as an example, the one used for giardiasis cases is available at http://www.phac-aspc.gc.ca/c-enternet/pdf/giardia-w_e.pdf). Detailed information on demographics and disease symptoms, as well as exposures to potential risk factors that may have occurred prior to the disease onset, was collected for each case. The exposure time period was different based on the incubation period for each disease: 2–4 weeks for amoebiasis, 1–12 days for cryptosporidiosis, 2–14 days for cyclosporiasis, and the last 25 days for giardiasis. The ROW Public Health authorities provided depersonalized epidemiological and microbacteriological data to C-EnterNet. Ethics approval was obtained through the ROW Public Health Ethics Review Committee in 2005.

Definitions and variables used

Since the focus was on sporadic, domestically acquired cases, outbreak-related cases and confirmed cases related to international travel were removed prior to analysis. Outbreak-related cases were identified by ROW Public Health on the basis of epidemiological or laboratory evidence. As detailed elsewhere [9], confirmed travel-related cases were defined as cases that travelled outside Canada prior to disease onset and for which the infection had probably occurred abroad considering the travel dates and the incubation period.

The variables analysed included the site of isolation, age, gender, occupation, disease symptoms (including hospitalization) and duration, and the

exposure to various potential risk factors. Age was categorized into the following discrete groups (in years): 0–4, 5–9, 10–14, 15–19, 20–24, 25–39, 40–59, and ⩾60. Occupation was categorized into agriculture/food processing worker (works in agriculture, including plant, animal, and fish farming), food handler (works in establishment where food is processed or served), daycare worker (works in or attends a daycare, either public or private), healthcare worker (works in a healthcare setting, involved in contact with patients, and including personal care providers, or residents of long-term care facilities) and other (those responses that did not fit into the previous four categories) to distinguish high-risk occupational exposures. Disease duration was calculated by subtracting recovery date from onset date whenever both dates were available. The potential risk factors were further grouped by main routes of transmission: exposure through water, animal/environment-to-person route, person-to-person route, and exposure to high-risk food. A case was assigned to a main transmission route whenever they reported at least one exposure to any of the potential risk factors defining the main transmission route. Assignment of a case to more than one main transmission route was possible. Cases with a missing or unsure response to one of the variables used to assign the case to any main transmission route were excluded. Finally, each case was considered to have been possibly infected through a single main transmission route, through multiple routes, or was considered as unclassifiable when it could not be assigned to any of the single or multiple transmission routes.

Data analysis

Each disease was analysed separately. Missing values and 'Unsure' answers were omitted when computing any statistics. Quartiles, means and their 95% confidence interval were used to describe continuous variables. Proportions and their 95% confidence interval were computed for categorical variables. Incidence rates were calculated for all the cases as well as for combined age and gender groups with 95% confidence intervals estimated according to Rothman & Greenland [16]. The mean population of the study community over the four years 2005–2009 was used for the denominators. The population data were provided by the Ontario Ministry of Finance [17]. Differences in incidence rates between age and gender groups were statistically tested using negative

binomial regression models without interaction and incidence rate ratios (IRR) with their 95% confidence interval were presented whenever differences were significant ($P < 0.05$). Logistic regression was performed to investigate the effect of age and gender on the presence/absence of symptoms and of potential risk factors for each disease. This last analysis was undertaken after age groups were further regrouped (0–9, 10–24, 25–39, ⩾40 years) and when at least 75 cases were available, so that the statistical power was over 80% when looking at odds ratios >4·0 for binary variables. PASS version 2005 (NCSS, USA) was used for the power analysis and SAS version 9.1 (SAS Institute Inc., USA) for all other analyses.

RESULTS

The number of sporadic, non-travel-related cases (and the crude incidence rate) were 68 (3·4/100 000 person-years) for amoebiasis, 57 (2·9/100 000 person-years) for cryptosporidiosis, 6 (0·3/100 000 person-years) for cyclosporiasis, and 176 (8·8/100 000 person-years) for giardiasis. All pathogens were detected in stool samples. Because of their small number, cyclosporiasis cases have not been further described.

Amoebiasis and giardiasis cases were more likely to be male (57% and 61%, respectively) and adults aged between 25 and 49 years (76% and 51%, respectively) (Table 1). The majority of cryptosporidiosis cases were more likely to be female (53%) and children aged <15 years (54%). The proportion of cases having a potentially high-risk occupational exposure was 10% for amoebiasis, 11% for cryptosporidiosis (5% being healthcare workers), and 9% for giardiasis (Table 1).

Incidence rates varied by gender, age, and disease (Fig. 1). No statistically significant differences were detected between genders for the three diseases. Compared to the 40–59 years age group, the incidence rate in cryptosporidiosis cases was significantly higher in the 5–9 years age group (IRR 18·8, 95% CI 13·6–48·0), whereas giardiasis incidence was highest in the 0–4 years (IRR 2·8, 95% CI 1·7–4·8) and the 5–9 years (IRR 3·3, 95% CI 2·0–4·8) age groups (Fig. 1). There were no statistically significant differences between age groups in the amoebiasis cases.

The number of sporadic, domestically acquired cases for which data on symptoms and risk-factor exposure data were missing because they could not be

Table 1. *Demographics of domestically acquired cases of amoebiasis, cryptosporidiosis and giardiasis cases reported in the Region of Waterloo, Ontario, June 2005–May 2009*

| Characteristics	Amoebiasis		Cryptosporidiosis		Giardiasis	
	n/N*	% (95% CI)	n/N*	% (95% CI)	n/N*	% (95% CI)
Gender						
Female	29/68	43 (35–51)	30/57	53 (45–60)	69/176	39 (27–52)
Male	39/68	57 (49–65)	27/57	47 (40–55)	107/176	61 (48–73)
Age (years), mean (s.d.)	37 (17)		20 (19)		27 (20)	
Min/Q11/median/Q3/max	2/28/39/48/73		1/6/12/31/87		1/8/29/43/83	
Age groups (years)						
0–4	4/68	6 (2–10)	9/57	16 (10–21)	21/176	12 (4–20)
5–9	3/68	4 (1–8)	12/57	21 (15–27)	27/176	15 (6–25)
10–14	2/68	3 (0–6)	10/57	18 (12–23)	14/176	8 (1–15)
15–19	2/68	3 (0–6)	2/57	4 (1–6)	5/176	3 (0–7)
20–24	0/68	0	4/57	7 (3–11)	6/176	3 (0–8)
25–39	24/68	35 (28–43)	13/57	23 (17–29)	51/176	29 (17–41)
40–59	28/68	41 (33–49)	4/57	7 (3–11)	39/176	22 (11–33)
⩾60	5/68	7 (3–12)	3/57	5 (2–9)	13/176	7 (1–14)
Occupation						
Agriculture/food processing	1/54	2 (0–4)	0/51	0	1/143	1 (0–3)
Food handler	2/54	4 (1–6)	2/51	4 (1–7)	5/143	3 (0–8)
Daycare worker	2/54	4 (1–6)	1/51	4 (0–4)	7/143	5 (0–10)
Healthcare worker	2/54	4 (1–6)	3/51	6 (3–9)	3/143	2 (0–5)
None of the above	47/54	87 (82–92)	45/51	88 (84–93)	127/143	89 (81–96)

CI, Confidence interval.

* *n* = Number of cases in that category; *N* = total number of respondents to that question (because all answers were not available from all interviewed cases, the denominator *N* is below or equal to the total number of cases interviewed within each disease).

interviewed was 14 (21%) for amoebiasis, 6 (11%) for cryptosporidiosis, and 33 (19%) for giardiasis. The three most common symptoms reported by amoebiasis and giardiasis cases were diarrhoea (70% and 84% of cases, respectively), abdominal pain (63% and 70%), and abdominal bloating (60% and 68%) (Table 2). For cryptosporidiosis, diarrhoea (100% of cases), abdominal pain (85%), and malaise (76%) were most commonly reported. Bloody diarrhoea was a symptom asked of all amoebiasis cases and reported by two. Bloody diarrhoea was not a symptom listed on the questionnaire for the other two diseases; nevertheless, two cryptosporidiosis cases, and four giardiasis cases reported this symptom when interviewed. Of the amoebiasis, cryptosporidiosis and giardiasis cases, 5%, 17% and 6%, respectively, were hospitalized. Onset and recovery dates were both available in subsets of interviewed cases: 11 (20%) cases for amoebiasis, 36 (71%) for cryptosporidiosis, and 47 (33%) for giardiasis. Disease durations were highly variable within each disease (Table 2). Their distribution spanned an approximately 3-week period

for cryptosporidiosis (median 10 days) and an approximately 11-week period for the other diseases (median 20–21 days) (Table 2).

The most frequent risk factors in amoebiasis cases were contact with household pets (39% of cases), attending any social gatherings (33%), and travelling within Canada (31%) (Table 3). For cryptosporidiosis cases, travel within Canada (100%), contact with household pets (49%), and swimming (46%) were most frequently reported. These same risk factors were reported for giardiasis cases (52%, 43%, and 44% of cases, respectively). For each of the three diseases, the animal/environment-to-person was the most common main transmission route for cases that provided usable answers to assign them to the possible main transmission routes, whereas the person-to-person route was the least common (Table 4). Furthermore, a minority of cases could be assigned to one exclusive main transmission route, the most common being the animal/environment-to-person route. No cryptosporidiosis cases, seven (32%) amoebiasis cases and 10 (15%) giardiasis cases
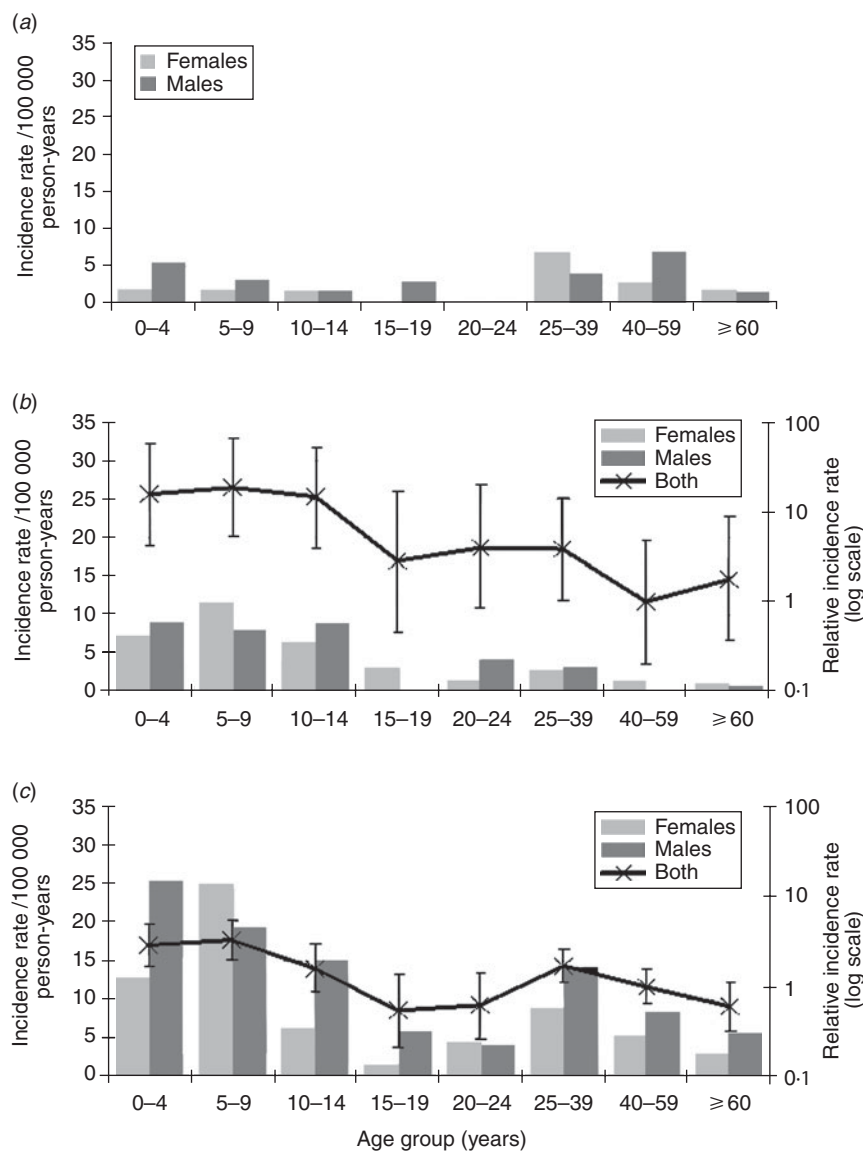
Fig. 1. Age- and gender-specific incidence rate of sporadic, domestically acquired (*a*) amoebiasis, (*b*) cryptosporidiosis and (*c*) giardiasis cases reported in the Region of Waterloo, June 2005–May 2009. The differences between age groups are shown for males and females together as the relative incidence rate with the 40–59 years age group being the reference. (Note a log scale was chosen for its scale on the right because of large differences between age groups and because of the width of some confidence intervals.)

could not be assigned to any main transmission routes (exposure through water, animal-to-person route, person-to-person route, exposure through high-risk food); hence they were considered unclassifiable based on the exposures reported by the interviewed cases (Table 4).

Differences between ages or genders in symptoms or potential risk factors could only be tested in giardiasis cases because the threshold (a minimum of 75 cases for statistical power) was achieved. Of these cases, statistically significant differences were observed between age groups only and for abdominal pain ($P = 0.038$), abdominal bloating ($P = 0.029$), fatigue ($P = 0.038$), swimming in recreational waters ($P = 0.022$), and attending a barbeque ($P = 0.040$). Cases in the 25–39 years age group reported more frequently having suffered from abdominal pain (88%), abdominal bloating (85%), whereas fatigue was increasingly reported with age (Fig. 2). The 10–24 years age group was the most exposed group for swimming in recreational waters (79%) and attending a barbeque (50%) (Fig. 2).

Table 2. *Clinical characteristics of amoebiasis, cryptosporidiosis and giardiasis cases reported in the Region of Waterloo, Ontario, June 2005–May 2009*

Characteristics	Amoebiasis		Cryptosporidiosis		Giardiasis	
	n/N*	% (95% CI)	n/N*	% (95% CI)	n/N*	% (95% CI)
Abdominal pain	22/35	63 (47–79)	35/41	85 (75–96)	77/110	70 (61–79)
Abdominal bloating	21/35	60 (44–77)	n.a.		71/105	68 (59–77)
Chills	5/29	17 (3–31)	n.a.		n.a.	
Dehydration	n.a.		n.a.		25/97	26 (17–34)
Diarrhoea	26/37	70 (56–85)	45/45	100 (92–100)	92/110	84 (77–91)
Bloody diarrhoea	2/30	7 (0–16)	n.a.		n.a.	
Fatigue	n.a.		n.a.		63/103	61 (52–71)
Fever	8/32	25 (10–40)	21/45	47 (32–62)	n.a.	
Loss of appetite	n.a.		24/40	60 (45–75)	n.a.	
Weight loss	n.a.		23/40	58 (42–73)	39/77	51 (39–62)
Malaise	n.a.		32/40	76 (63–89)	n.a.	
Nausea	n.a.		23/40	59 (43–74)	n.a.	
Vomiting	5/8	63 (29–96)	28/44	64 (49–78)	15/30	50 (32–68)
Hospitalization	2/37	5 (0–13)	7/42	17 (5–28)	7/111	6 (2–11)
Disease duration (days)	$n' = 11$		$n' = 36$		$n' = 47$	
Min/Q1/median/Q3/max	4/4/20/30/76		2/6/10/14/21		2/11/21/33/81	

CI, Confidence interval; n.a., not applicable.

* n = Number of cases that answered yes; N = number of cases that answered yes or no (because all answers were not available from all interviewed cases, the denominator N is below or equal to the total number of cases interviewed within each disease).

n' = Number of cases for which the data was available.

DISCUSSION

This study provides a current, comprehensive epidemio-clinical picture of sporadic, domestically acquired cases of amoebiasis, cryptosporidiosis and giardiasis in one Canadian community based on data gathered from an enhanced surveillance system. The observed crude incidence rates in this study for the sporadic, domestically acquired cases of amoebiasis, cryptosporidiosis, and giardiasis were comparable to the age-standardized rates computed for all cases in ROW over the same time period, which in turn were similar to the rates observed across Ontario [18]. Higher incidence rates for cryptosporidiosis (6·0) and giardiasis (19·6) have been reported in another Canadian community over the years 1999–2002 [19]. The difference may be due to the different time period used in each study, since the incidence of giardiasis has been decreasing in ROW and in Ontario since 1990 [20]. Epidemiologically, the study confirms a higher incidence rate in children aged <5 years for cryptosporidiosis and <10 years for giardiasis, as observed in other Canadian and foreign studies [12, 20–22]. Conversely, this study illustrates that amoebiasis is relatively rare in children aged <10 years.

This study did not find differences in incidence between genders, as has been reported in some studies [20, 22], while others have reported higher cryptosporidiosis or giardiasis rates in males [12, 19, 21, 23]. Therefore, the effect of gender is still to be elucidated.

Clinically, the symptoms reported by the cases and the disease durations were consistent with the symptoms and duration generally associated with each illness [24–28]. Chills, bloody diarrhoea and fever were reported by a minority of amoebiasis cases (<25%), possibly attributable to the dysentery form of the amoebic infection. The increasing report of fatigue with age in giardiasis cases might reflect a physiological phenomenon related to ageing. The higher proportion of giardiasis cases with abdominal pain and abdominal bloating in the 25–39 years age group was unexpected. These two symptoms, common in the general population in North America [29, 30], are not specific to parasitic infections as they may be related to other illnesses as well to functional gastrointestinal disorders [31]. Differences between ages and the occurrence of abdominal bloating or pain in the general population or in diseased people have been rarely documented and, when they are, results have not been provided to develop a consistent understanding of an

age effect [29, 30, 32]. The observation that abdominal pain and abdominal bloating are more common in people aged 25–39 years might suggest more frequent functional gastrointestinal disorders in young adults (in the absence of infection), and warrants further study.

Overall, most cryptosporidiosis and giardiasis cases had been exposed to at least one potential risk factor falling under the animal/environment-person route, the exposure through water, or the exposure through high-risk food (in order of decreasing frequency). By grouping potential risk factors to identify exclusive main transmission we discovered that multiple main transmission routes were possible for many cases. Of the cases where reported exposures allowed categorizing the case into a single possible route category, the animal/environment-to-person route was the most common route. Since two thirds of cases could be categorized into one possible main transmission route based on reported exposures, these results are consistent with the general epidemiology of diseases, highlighting the importance of livestock and companion animals as main reservoirs of these microparasitic pathogens. In addition, this further supports the growing body of evidence that indicates drinking water, recreational water and contact with animals or their environment are the major transmission routes for parasitic infections [1, 2, 22, 33–37]. However, nearly one third of cases could not be assigned into a category of single or multiple possible main transmission routes, possibly due to misclassification of exposure or because the transmission was foodborne (other than high-risk food). Nevertheless, those unclassifiable cases highlight the limitations of assessing exposures through current methods, and potential gaps in knowledge of risk factors for these diseases.

The effect of age on the occurrence of giardiasis was significant for two risk factors: swimming and attending a barbeque, with a greater proportion of cases in the 10–24 years age group. A healthy control survey performed in the same study site in 2010 (C-EnterNet, unpublished data) showed that swimming in a pool and contact with recreational water (natural swimming venues) both decrease with age in the general healthy population (i.e. without gastrointestinal illness) (C-EnterNet, unpublished data), strengthening the hypothesis that recreational water is a risk factor specific to individuals in the 10–24 years age group. The same study failed to identify more frequent attendance at barbeques in the 10–24 years age group of healthy controls (C-EnterNet, unpublished data), hence strengthening the hypothesis that attending a barbeque may be a risk factor specific to this population age group as well.

One limitation of the study is that only genus-level characterization of the stool samples was done for the parasite analysis of human infections. The *Cryptosporidium* genus includes various species that have various virulences with regard to humans and various specific reservoirs [34]. *C. parvum* and *C. hominis* are the two species with the greatest public health importance, the first characterized by a zoonotic transmission and the second by an anthroponotic transmission [1, 34, 37, 38]. Similarly, *Giardia lamblia* includes a few assemblages of various public health importance and epidemiology [2, 34]. With respect to amoebiasis, two microscopically indistinguishable species are found by diagnostic laboratories in patients' stool, one being pathogenic (*Entamoeba histolytica*) and the other non-pathogenic (*E. dispar*), with the latter being more frequent than the former [39]. As a result, the amoebiasis cases described herein were probably a mix of actual *E. histolytica* infections and of cases attributed to the non-pathogenic *E. dispar* and for which the actual disease aetiology is unknown. This clearly limits the interpretation of the epidemiological and clinical description of those cases. Future epidemio-clinical description of those parasitic diseases should take into account the genotypic diversity in the aetiological agents. Furthermore, molecular typing of positive stool samples for parasitic infections in Canadian diagnostic laboratories is advocated to better inform prevention and control efforts.

Another limitation of this study is that the analysis is restricted to one community, which may not be representative of the rest of Canada with respect to the diseases under study. Finally, the epidemio-clinical description of the cases may suffer from bias and measurement errors. Because the study was based on reported cases, there might be significant differences between those cases and cases that do not visit a physician, submit a stool sample, and get reported. In addition, measurement error may be introduced when the case is interviewed. For example, the patient might remember certain symptoms over others, or only remember exposure to certain potential risk factors at the time of the follow-up interview. Those potential measurement errors may lead to misclassification of exposure route. In particular, some cases of those regrouped into the 'unclassifiable' category might actually have been exposed through

Table 3. *Exposure to known potential risk factors in amoebiasis, cryptosporidiosis and giardiasis cases reported in the Region of Waterloo, Ontario, June 2005–May 2009*

Exposure	Amoebiasis		Cryptosporidiosis		Giardiasis	
	n/N^*	% (95% CI)	n/N^*	% (95% CI)	n/N^*	% (95% CI)
Main source of drinking water						
Private well	3/54	6 (12–15)	16/51	31 (19–46)	33/143	23 (16–31)
Municipal/city water	41/54	76 (62–87)	25/51	49 (35–63)	87/143	61 (52–69)
Bottled water	26/54	48 (34–62)	27/51	53 (39–67)	73/143	51 (43–60)
Used an in-home treatment system for drinking water	11/45	24 (13–04)	12/50	24 (13–38)	31/122	25 (18–34)
Reverse osmosis	3/45	7 (1–18)	2/43	5 (1–16)	4/116	3 (1–9)
Ultraviolet light	0/45	0 (0–8)	1/43	2 (0–12)	2/116	2 (0–6)
On-tap filter	3/45	7 (1–18)	3/43	7 (2–19)	9/116	8 (4–14)
Water pitcher filter (such as Brita)	5/45	11 (4–24)	6/43	14 (5–28)	14/116	12 (7–19)
Drank untreated/raw water prior to disease onset	4/42	10 (3–23)	5/46	11 (4–24)	24/123	20 (13–28)
Swam in/gone into any of the following prior to disease onset	9/44	20 (10–40)	22/48	46 (31–61)	58/132	44 (35–53)
Ocean	0/42	0 (0–8)	0/45	0 (0–8)	3/118	3 (1–7)
Lake	6/42	14 (5–29)	10/45	22 (11–37)	25/118	21 (14–30)
River	0/42	0 (0–8)	2/45	4 (1–15)	9/118	8 (4–14)
Pool	3/42	7 (2–20)	9/45	20 (10–35)	34/118	29 (21–38)
Hot tub	2/42	5 (1–16)	1/45	2 (0–12)	6/118	5 (2–11)
Canoed, kayaked, hiked, or camped prior to disease onset	4/46	9 (2–21)	8/49	16 (7–30)	16/128	13 (7–20)
Drank or ate any unpasteurized milk, juice, or dairy products prior to disease onset	4/44	9 (3–22)	4/50	8 (2–19)	6/121	5 (2–11)
Unpasteurized milk	2/43	5 (1–16)	4/39	10 (3–24)	6/111	5 (2–11)
Unpasteurized juice	0/43	0 (0–8)	0/39	0 (0–9)	1/111	1 (0–5)
Unpasteurized dairy products	1/43	2 (0–12)	0/39	0 (0–9)	3/111	3 (1–8)
Ate meat from any place other than the grocery store prior to disease onset	5/42	12 (4–26)	12/47	26 (14–40)	25/120	21 (14–29)
Hunting	0/42	0 (0–8)	0/41	0 (0–9)	1/114	1 (0–5)
Butcher shop	0/42	0 (0–8)	6/41	15 (6–29)	18/114	16 (10–24)
Private kill	2/42	5 (1–16)	4/41	10 (3–23)	7/114	6 (3–12)
Shopped for food eaten the week before illness at						
Supermarket	37/43	86 (72–95)	43/46	93 (82–99)	119/127	94 (88–97)
Farmer's market	4/43	9 (3–22)	2/46	4 (1–15)	14/128	11 (6–18)
Butcher shop	2/43	5 (1–16)	9/46	20 (9–34)	17/127	13 (8–21)
Farm (laneway)	2/43	5 (1–16)	3/46	7 (1–18)	3/127	2 (1–7)
Hosted or attended a barbeque prior to disease onset	8/42	19 (9–34)	15/45	33 (20–49)	32/119	27 (19–36)
Attended social gatherings (wedding, receptions, showers, parties, festivals, fair, etc.) prior to disease onset	14/43	33 (19–49)	9/49	18 (9–32)	31/125	25 (18–33)
Lived on a farm or country property prior to disease onset	3/44	7 (1–19)	15/50	30 (18–45)	27/127	21 (15–29)
Visited a farm, a petting zoo or a fair prior to disease onset	9/44	20 (10–35)	9/49	18 (9–32)	20/128	16 (10–23)
Gardened prior to disease onset	8/44	18 (8–33)	6/47	13 (5–26)	24/127	19 (13–27)

Table 3 (*cont.*)

Exposure	Amoebiasis		Cryptosporidiosis		Giardiasis	
	n/N*	% (95% CI)	n/N*	% (95% CI)	n/N*	% (95% CI)
Contact with household pets prior to disease onset	18/46	39 (25–55)	24/49	49 (34–64)	58/133	43 (35–53)
Dog	12/39	31 (17–48)	19/38	50 (33–67)	34/93	37 (27–47)
Cat	9/40	23 (11–39)	7/38	18 (8–34)	21/93	23 (15–32)
Bird	1/40	3 (0–13)	1/38	3 (0–14)	3/93	3 (1–9)
Reptile	2/39	5 (1–17)	1/38	3 (0–14)	4/93	4 (1–11)
Rodent	0/39	0 (0–9)	0/38	0 (0–9)	1/93	1 (0–6)
Travelled within Canada prior to disease onset	4/13	31 (9–61)	10/10	100 (69–100)	15/29	52 (33–71)
Knew anyone else outside the household with a diarrhoeal illness prior to disease onset	2/39	5 (1–17)	6/48	13 (5–25)	20/121	17 (10–24)
Ate food prepared outside of the home prior to disease onset	23/41	56 (40–72)	20/47	43 (28–58)	72/122	59 (50–68)
Restaurant	13/45	29 (16–44)	10/46	22 (11–36)	47/121	39 (30–48)
Cafeteria	1/45	2 (0–12)	2/46	4 (1–15)	9/121	7 (4–14)
Delicatessen	1/45	2 (0–12)	1/46	2 (0–12)	6/121	5 (2–10)
Ready-to-eat food	1/45	2 (0–12)	2/46	4 (1–15)	5/121	4 (1–9)
Fastfood restaurant	11/45	24 (13–40)	16/46	35 (21–50)	30/121	25 (17–34)
Food vendor	0/45	0 (0–8)	2/46	4 (1–15)	6/121	5 (2–11)
Ate any food that was undercooked	3/39	8 (2–21)	0/47	0 (0–8)	4/108	4 (1–9)
Ate any food that did not taste right (spoiled)	2/39	5 (1–17)	0/49	0 (0–7)	4/110	4 (1–9)

CI, Confidence interval.

* n = Number of cases that answered yes; N = number of cases that answered yes or no (because all answers were not available from all interviewed cases, the denominator N is below or equal to the total number of cases interviewed within each disease).

either a single main transmission route, and some cases might have been exposed to more than one single route. In addition, the resulting clinical picture of the case does not include a measure of exposure over time, and the duration or severity of each reported symptom.

This study was based on an enhanced passive surveillance of human gastrointestinal illnesses in the context of the C-EnterNet, a sentinel site integrated surveillance programme facilitated by the Public Health Agency of Canada. The programme was developed to detect changes in trends in human enteric disease and in levels of pathogen exposure from food, animal and water sources (http://www.phac-aspc.gc.ca/c-enternet/index-eng.php). Within each sentinel site, agreements with the local public health authority and the private and public health laboratories serving the area of the site allows the programme to acquire epidemiological and laboratory data from almost each human case of reportable enteric parasitic or bacterial diseases. Because of the rich and new data it has generated and disseminated,

the interest in and support for this programme within the Canadian public health community is growing. Beyond the funding provided to the partners, the genuine collaboration and the sharing of resources, methods, expertise, results and successes have helped to make this idea of integrated surveillance a reality. Starting in 2005 with a first sentinel site, C-EnterNet enrolled a second site in 2010 with a plan to ultimately implement five sentinel sites across Canada encompassing 3 million inhabitants (one tenth of the Canadian population).

This study fills in some major knowledge gaps with respect to the basic information used to estimate the burden of parasitic diseases in Canadian communities, including rates of hospitalization, the prevalence of bloody diarrhoea in cases (a surrogate for severity), and disease duration. In addition to the mean estimates of those parameters, the study provides a mechanism to evaluate the variability of various parameters for future disease burden modelling, e.g. disease duration. The findings help to emphasize the importance of collecting standardized and enhanced

Table 4. *Categories of domestically acquired cases of amoebiasis, cryptosporidiosis and giardiasis cases reported in the Region of Waterloo, Ontario, June 2005–May 2009, by possible main transmission routes according to exposures to known potential risk factors as reported by the cases*

Transmission routes	Amoebiasis ($n=22$)*		Cryptosporidiosis ($n=32$)*		Giardiasis ($n=65$)*	
When routes are considered separately (a case can be assigned to more than one category except those in the last one)						
Exposure through water	5	23%	17	53%	33	51%
Animal/environment-to-person	13	59%	23	72%	44	68%
Person-to-person	1	5%	5	16%	11	17%
Exposure through high risk food	7	32%	16	50%	29	45%
Unclassifiable†	7	32%	0	0%	10	15%
When all routes are considered together (each case was assigned to one possible route only)						
One single route possible:						
Exposure through water	1	5%	4	13%	2	3%
Animal/environment-to-person	7	32%	7	22%	9	14%
Person-to-person	0	0%	1	3%	0	0%
Exposure through high risk food	0	0%	0	0%	5	8%
Multiple routes possible	7	32%	20	62%	39	60%
Unclassifiable†	7	32%	0	0%	10	15%
Total	22	100%	32	100%	65	100%

* Interviewed cases with unsure or missing answers were removed prior to the grouping into possible main transmission routes.

† Whenever the case cannot be classified under any of the other possible main transmission routes.
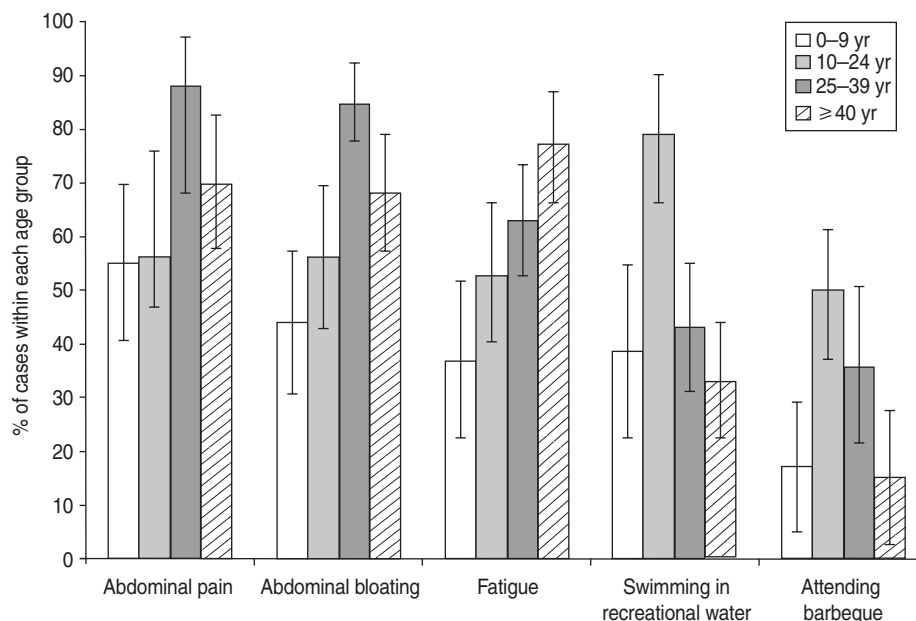

Fig. 2. Symptoms and exposures (% with 95% confidence intervals) for which there were statistically significant age differences in reported giardiasis cases in the Region of Waterloo, Ontario, June 2005–May 2009.

information of all cases of enteric diseases at the community level in Canada, to help inform prevention and control measures at the local, provincial and federal levels.

In conclusion, this study provides a current, comprehensive epidemio-clinical picture of sporadic, domestically acquired cases of three reportable parasitic infections in one Canadian community based on data gathered from an enhanced surveillance system including a systematic and standardized follow-up of all reported cases. The results will be useful for future research to estimate the burden

of parasitic diseases – an endeavour of growing interest in Canada and elsewhere. This study also highlights the value of enhanced human disease surveillance, which will further benefit from the collection and analysis of genotypic data from the human isolates in conjunction with epidemiological case information.

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DECLARATION OF INTEREST

None.

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