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A comparison of exposure to risk factors for giardiasis in non-travellers, domestic travellers and international travellers in a Canadian community, 2006–2012

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SUMMARY

The purpose of this study is to determine how demographic and exposure factors related to giardiasis vary between travel and endemic cases. Exposure and demographic data were gathered by public health inspectors from giardiasis cases reported from the Region of Waterloo from 2006 to 2012. Logistic regression models were fit to assess differences in exposure to risk factors for giardiasis between international travel-related cases and Canadian acquired cases while controlling for age and sex. Multinomial regression models were also fit to assess the differences in risk profiles between international and domestic travel-related cases and endemic cases. Travel-related cases (both international and domestic) were more likely to go camping or kayaking, and consume untreated water compared to endemic cases. Domestic travel-related cases were more likely to visit a petting zoo or farm compared to endemic cases, and were more likely to swim in freshwater compared to endemic cases and international travel-related cases. International travellers were more likely to swim in an ocean compared to both domestic travel-related and endemic cases. These findings demonstrate that travel-related and endemic cases have different risk exposure profiles which should be considered for appropriately targeting health promotion campaigns.

Key words: Giardiasis, travellers' infection.

INTRODUCTION

International travel, especially to countries with developing economies, has markedly increased over the past decade with over 1 billion international tourist arrivals, and 5–6 billion domestic tourist arrivals worldwide in 2013 [1]. Travellers can contract infectious gastrointestinal (GI) illness outside their country of residence and therefore can contribute to the global spread of infectious diseases [2–5]. Regions where travellers are at greatest risk of contracting infectious diarrhoea include South America, Sub-Saharan Africa and South Asia [2]. *Giardia duodenalis,* an enteric flagellated protozoan parasite, is the most commonly reported parasitic cause of traveller's diarrhoea, particularly chronic diarrhoea [4, 6, 7]. Infection with *Giardia* can result in the following signs and symptoms: nausea, weight loss, bloating, abdominal pain, diarrhoea and malabsorption, and in severe cases, failure to thrive in children [8].

Infection with *Giardia* occurs via the faecal–oral route by either direct (e.g. person-to-person) or

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indirect (e.g. contaminated food or water) contact. *Giardia* is particularly well suited for waterborne transmission, and is consequently a frequent cause of waterborne enteric infections [9, 10]. Although waterborne transmission is common, foodborne outbreaks of giardiasis have also been reported due to contamination from food handlers or contaminated water [11, 12]. In countries with developing economies, infections are often associated with poor sanitary conditions, inadequate water treatment, and overcrowding [13], whereas in industrialized nations, cases are often associated with crowding in institutionalized settings (e.g. day care) [14], exposure to recreational water [15], international travel, and immigration [7].

Giardia infections place a large burden on public health in Canada, with approximately 13·1 reported cases/100 000 person-years [16]. In the Region of Waterloo (ROW), located in southern Ontario, giardiasis is one of the top three most frequently reported infectious diseases, and has the ninth highest age-standardized rate of all reportable diseases in the ROW [17]. In this region, there were approximately 8·8 cases/100 000 person-years in 2006–2009 [18]. Therefore, giardiasis constitutes a significant issue for this region.

Increasing immigration to Canada coupled with the increasing number of Canadians travelling abroad is expected to significantly impact the burden of illness due to enteropathogens, including *Giardia*, in Canada [4]. From 2007 to 2009, 39% of giardiasis cases in Ontario were acquired while travelling outside of Canada; suggesting international travel can have a large impact on the burden of illness due to giardiasis in Ontario [19]. When estimating this burden of illness, travel cases are considered to be distinct from domestically acquired cases due to differences in control measures in other countries [4, 20]. However, even though international travel-related cases (ITRCs) and domestic cases are differentiated, most studies do not distinguish between domestic travel and endemic cases (ECs) as these two categories are traditionally grouped together. As such, there has been no published research where domestic travel-related cases (DTRCs) have been analysed separately from ECs. This potentially represents a considerable knowledge gap, as risk factors for contracting giardiasis via domestic travel may be different from those associated with endemic giardiasis or international travel. Therefore, the objectives of this study were to:

(1) Describe the most common travel destinations for giardiasis cases associated with international travel.
(2) Determine how demographic factors and exposure to risk factors for giardiasis vary in ITRCs and Canadian cases.
(3) Determine how demographic factors and exposure to risk factors for giardiasis vary in ITRCs, DTRCs and ECs (i.e. cases acquired in the ROW) of giardiasis.
(4) Assess the impact of grouping domestic travel and ECs together for comparison with cases related to international travel on our understanding of the epidemiology of giardiasis.

METHODS

Study population and time frame

The data for this retrospective study were obtained from the Canadian National Integrated Enteric Pathogen Surveillance Program, FoodNet Canada. Specifically, they were gathered from the Public Health Agency of Canada's (PHAC) FoodNet Canada's sentinel surveillance site in the ROW, Ontario, Canada. The ROW is home to approximately 500 000 residents divided between the cities of Kitchener, Cambridge and Waterloo, as well as the four rural townships of Woolwich, Wellesley, Willmont and North Dumfries (http://mpas.region.waterloo.on.ca/locator/locator.htm). The study period included cases reported from January 2006 to November 2012, inclusive.

Surveillance data collection

FoodNet Canada is a surveillance programme that monitors illnesses caused by enteric pathogens that are reportable in Canada (e.g. giardiasis), with the goal of reducing the burden of enteric disease in Canada. In Canada, it is mandatory for diagnostic laboratories to report all confirmed notifiable diseases to the local health authority and in Ontario microscopy is used for the identification of giardiasis cases. FoodNet Canada enhanced this existing laboratory-based surveillance system in the ROW by implementing a systematic follow-up of each reported giardiasis case by a ROW public health inspector using a standardized questionnaire specific to giardiasis cases. Detailed information on disease and demographic factors, as well as exposures to potential risk factors that may have occurred up to 25 days prior to the onset of illness were collected. The ROW health authorities provided FoodNet Canada with de-personalized epidemiological data for all giardiasis cases reported in the region. Ethical approval was obtained through the ROW Public Health Ethics Review Committee in 2009.

Data management and variables used

Outbreak-related cases, as determined by ROW Public Health, were removed from the dataset. Fields which were coded as unsure or unknown were re-coded as missing. The remaining cases were classified as acquired in Canada or acquired while travelling internationally for subsequent logistic regression analyses. For multinomial regression analyses, cases were classified as endemic, domestic travel- or international travel-related. For all case definitions, a minimum and a maximum incubation period of 3–25 days was chosen, according to previous work by Ravel [4]. The definition of an ITRC was adopted from Ravel *et al*. [4]. Briefly, it was defined as a case for which travel outside of Canada prior to disease onset was recorded and the expected incubation period overlapped with the travel time. A Canadian case (CC) was defined as any case of giardiasis which was acquired within Canada. These cases were divided into DTRCs and ECs. A DTRC was defined as a case for which travel within Canada, outside of the ROW, was recorded prior to disease onset, and the expected incubation period overlapped with the travel time. Cases not classified as an ITRC or DTRC were considered to be ECs (i.e. acquired within the ROW).

Travel destinations were grouped into the following categories: Africa, Asia, Europe, Americas (i.e. the Caribbean, Central and South America), and the United States. An 'other' category was used for cases that visited other parts of the world that did not fit into the previous categories (e.g. Australia), as well as cases that visited destinations in multiple categories. Age was categorized based on quartiles, into the following age groups: 0–8, 9–27, 28–43 and $\geqslant$44 years. Seasons were categorized in the following manner: winter (December–February), spring (March–May), summer (June–August), and autumn (September–November).

The variables used for multivariable analyses included: age, gender, season, exposure to companion animals (reptile, birds, cats, dogs, horses, rodents, other), exposure to environmental contaminants (manure/compost/organic fertilizers, visited a petting zoo or farm), exposure to recreational water (swam in a pool, ocean, river, lake, hot tub, or went camping/kayaking), drank untreated water, and exposure to unpasteurized foods or foods prepared outside of the home (attended a social event where food was consumed, consumed unpasteurized juice or milk, ate food purchased from a food vendor, delicatessen, restaurant, fast-food chain or cafeteria). As age was not linearly associated with the log odds of the outcome, it was categorized based on quartiles.

Statistical analyses

All statistical analyses were performed using Stata v. 13 for Windows (StataCorp., USA). All graphs were prepared using Microsoft Excel for Windows (Microsoft, USA). To determine which variables should be used in multivariable models, univariable analyses were conducted using either logistic or multinomial regression analyses, with a liberal P value of 0·2. These variables were subsequently tested and reported in multivariable analyses, as described below.

Canadian acquired *vs*. international travel analysis

For analyses comparing CCs *vs*. ITRCs, multivariable logistic regression models were built using the 'logit' command in Stata. In these models, we compared the exposure to a risk factor for giardiasis in ITRCs compared to CCs, while controlling for age and gender. Significance of the risk factor was determined using an α value of 0·05, and significance of a categorical variable within the model was examined using a Wald χ^2 test [21], using the 'test' command in Stata. Many risk factors, some subcategories of others, were causally unrelated, but using a causal diagram, age and gender were considered to be *a priori* confounders for all of the variables in our study. Therefore, age and gender were forced into all models, regardless of significance, to control for their potential confounding effects. Interaction terms were generated between all risk factors and age or gender. Interaction terms were assessed for statistical significance within each respective multivariable model, using a manual forward procedure. If significant interaction effects were present in the model, contrasts were constructed to examine the relationships between the variables [21]. Contrasts were also constructed to examine relationships between all categorical variables; all significant contrasts were reported [21].

International travel *vs.* domestic travel *vs.* endemic analysis

For analyses comparing ITRCs and DTRCs with ECs, multivariable multinomial regression models were built using the 'mlogit' command in Stata. A multinomial logistic regression model is for analysing nominal data, which relates to the probability of being in a category (e.g. ITRC or DTRC), to the baseline category (e.g. EC). However, it is important to note that the model does not make any assumptions about the order of the categories. These models were built in the same manner as the Canadian-acquired *vs.* international travel models. All relationships between international travel cases and domestic travel cases were compared and significant differences in exposures to risk factors in the cases are reported within the text. Contrasts were constructed to examine relationships between variables, to determine if they were part of a significant interaction, and to compare categories within a categorical variable.

RESULTS

Travel

Over the 6-year study period (2006–2012), 473 giardiasis cases were reported to the ROW, but one case was removed from the dataset for subsequent analyses as it was related to an outbreak. Of the 472 remaining cases, 191 (40%) were ITRCs and 281 (60%) were CCs. Of the cases acquired in Canada, 29 (10%) cases were related to domestic travel, and the remaining cases were acquired within the ROW. Of the ITRCs, 75 (40%) cases had travelled to Asia (Fig. 1), in particular, India, Pakistan and Bangladesh (Fig. 2*a*). Travel to the Americas and Africa were the second and third most visited travel categories by cases (Fig. 1). Cuba was the most common destination in the Americas for cases (Fig. 2*b*), whereas Kenya and Ethiopia were the most common destinations in Africa (Fig. 2*c*). Travel to Europe had the fewest number of reported giardiasis cases, compared to other travel destinations (Fig. 1). The reason for international travel included: pleasure (15 cases), visiting friends and relatives (eight cases), business (one case), and other (five cases). For the remaining 161 international travel cases, there was no information recorded about the reason for travel. Eighteen percent (out of 99 responses) received travel health information prior to travelling internationally. Locations for domestic travel were not recorded, but the reason for travelling was recorded for five of the 29 DTRCs. These reasons included, rural/backpacking (two cases), pleasure (two cases), and business (one case). There were no DTRCs that obtained travel health advice prior to travel out of 14 responses.

Exposures to risk factors for giardiasis in ITRCs compared to CCs (logistic regression model)

The majority of giardiasis cases occurred in males compared to females, with males accounting for 168 (56·8%) CCs and 108 (59·8%) ITRCs. However, there was no significant difference in distribution of genders between ITRCs and CCs (Tables 1–3). ITRCs were more likely to go camping/kayaking/canoeing (Table 1), drink untreated water, swim in an ocean (Table 2), or eat food from a food vendor or at a social gathering (Table 3) compared to CCs, after controlling for age and gender. By contrast, ITRCs were significantly less likely to be in contact with manure/organic fertilizer compared to CCs (Table 1).

Exposures to risk factors for giardiasis in ITRCs and DTRCs compared to ECs (multinomial regression model)

In general, the lowest percentage of missing observations was for DTRCs and the highest percentage of missing observations was for ECs (Table 4). DTRCs had the fewest number of observations available for analysis (maximum $n = 29$), compared to ITRCs (maximum $n = 191$) and ECs (maximum $n = 252$) (Table 4). Overall, there were more cases that were male, compared to female in all three case groups. However, there was no significant difference in distribution of genders between ITRCs, DTRCs and ECs, regardless of which case type was examined as the referent outcome ($P > 0{\cdot}2$ for all models with DTRCs as the referent outcome) (Tables 5–7). DTRCs were significantly more likely to have a pet cat, visit a petting zoo, go camping/kayaking/canoeing (Table 5), swim in a river or lake, drink untreated water (Table 6), or eat food from a cafeteria, delicatessen or restaurant (Table 7) compared to ECs, after controlling for age and gender. ITRCs were significantly less likely to own a cat [odds ratio (OR) 0·17, 95% confidence interval (CI) 0·062–0·45, $P < 0{\cdot}001$], go camping/kayaking/canoeing (OR 0·39, 95% CI 0·15–0·99, $P = 0{\cdot}048$), have contact with manure (OR 0·17, 95% CI

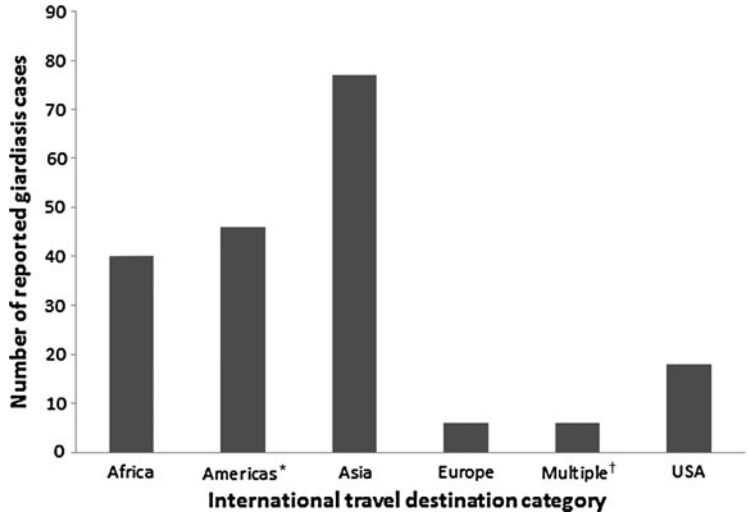

Fig. 1. Number of international travel-related giardiasis cases reported to the FoodNet Canada programme, Region of Waterloo sentinel site, attributed to various travel destinations from 2006 to 2012. * Americas includes Mexico, South America, Central America and the Caribbean. † Multiple includes travel to at least two different destination categories within one trip.

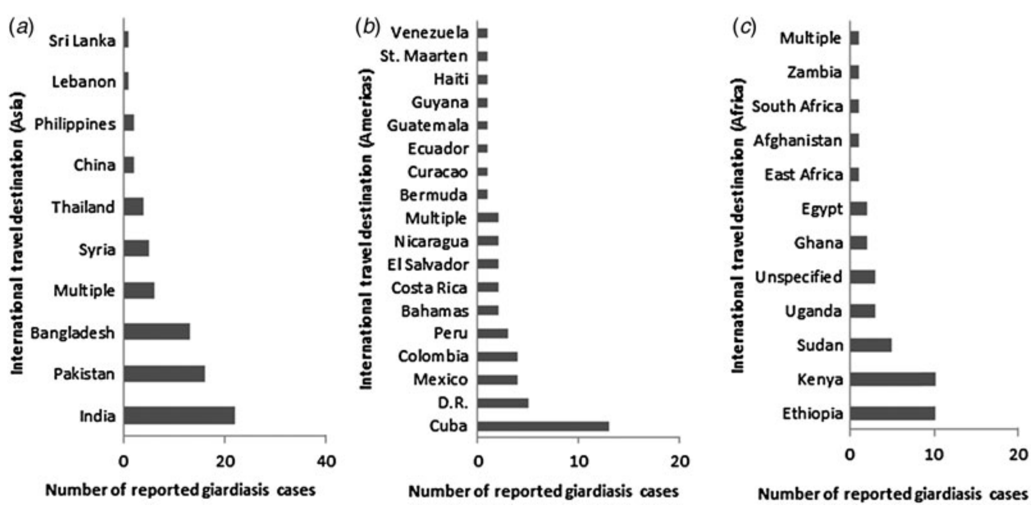

Fig. 2. Number of international travel-related giardiasis cases reported to the FoodNet Canada programme sentinel site in the Region of Waterloo from 2006 to 20 012, attributed to specific countries within the top three travel destination categories: (*a*) Asia, (*b*) Americas, and (*c*) Africa. Note that 'multiple' indicates travel to multiple countries within one specific travel destination category and 'unspecified' indicates that a specific country within that particular destination category was not identified. D.R., Dominican Republic.

0·049–0·56, $P = 0{\cdot}004$), go swimming in a river (OR 0·29, 95% CI 0·90–0·93, $P = 0{\cdot}037$) or lake (OR 0·13, 95% CI 0·047–0·35, $P = 0{\cdot}037$), or eat food purchased from a delicatessen (OR 0·16, 95% CI 0·034–0·80, $P = 0{\cdot}025$) compared to DTRCs after controlling for gender and age. However, ITRCs were significantly more likely to have gone swimming in an ocean than DTRCs (OR 14·89, 95% CI 0·034–0·80, $P = 0{\cdot}025$). ITRCs were also more likely to go camping/kayaking/canoeing (Table 5), swim in a river, ocean or pool, or drink untreated water compared to ECs (Table 6), after controlling for age and gender. However, ITRCs were less likely to have contact with manure or organic fertilizer than ECs (Table 5).

Temporal and seasonal trends

The total number of giardiasis cases reported each year varied, with the greatest number of cases reported in 2008 and the fewest in 2007 (Fig. 3). Cases were

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Table 1. *Statistically significant multivariable logistic regression analyses examining the exposure to companion animal and environmental risk factors for giardiasis in ITRCs compared to CCs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variable	OR	95% CI	*P* value
Contact with organic fertilizer or manure	Exposed to manure			
	Not exposed	Referent		
	Exposed	0·22	0·087–0·55	0·001
	Age (years)			
	0–8	Referent		
	9–27	0·97	0·52–1·82	0·93
	28–43	0·67	0·36–1·23	0·20
	⩾44	0·97	0·53–1·79	0·93
	Gender			
	Female	Referent		
	Male	0·85	0·55–1·32	0·47
Camping, kayaking or canoeing	Camping, kayaking or canoeing			
	Not exposed	Referent		
	Exposed	2·41	1·23–4·73	0·01
	Age (years)			
	0–8	Referent		
	9–27	0·82	0·43–1·57	0·55
	28–43	0·46	0·25–0·85	0·013
	⩾44	0·76	0·42–1·38	0·37
	Gender			
	Female	Referent		
	Male	0·88	0·57–1·37	0·58
Season	Season			
	Winter	Referent		
	Spring	1·58	0·93–2·70	0·092
	Summer	0·75	0·43–1·28	0·30
	Autumn	0·40	0·44–1·38	0·40
	Age (years)			
	0–8	Referent		
	9–27	0·97	0·58–1·62	0·89
	28–43	0·52	0·30–0·88	0·015
	⩾44	0·79	0·46–1·34	0·38
	Gender			
	Female	Referent		
	Male	0·88	0·60–1·29	0·78

ITRC, International travel-related case; CC, Canadian case; OR, Odds ratio; CI, confidence interval.

more likely to be an ITRC compared to a DTRC in 2009 compared to 2008 (OR 5·27, 95% CI 1·03–26·77, $P = 0·045$). Cases were also more likely to be an ITRC compared to a DTRC in 2012 compared to 2008 (OR 4·18, 95% CI 1·001–17·47, $P = 0·05$). However, there was no linear trend seen over time in the number of cases per year, nor the number of cases per case type (e.g. international, domestic) (Fig. 3). There was an evident seasonal trend in ECs, with the number of reported cases peaking in the late summer and early autumn months (July to October) (Fig. 4). ITRCs showed a small peak in the spring months (March–May), whereas the peak in reported DTRCs occurred in September. When examined using multivariable logistic regression analysis, cases were significantly more likely to be an ITRC compared to a CC in spring compared to summer (OR 2·12, 95% CI 1·28–3·50, $P = 0·003$) and in spring compared to autumn (OR 2·02, 95% CI 1·19–3·45, $P = 0·010$). Similarly, when examined using multivariable multinomial regression analysis, cases were significantly more likely to be ITRCs compared to DTRCs in spring compared to summer (OR 3·62, 95% CI 1·05–12·45, $P = 0·042$) and in spring compared to autumn (OR 5·02, 95% CI 1·48–16·99, $P = 0·009$).

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Table 2. *Statistically significant multivariable logistic regression analyses examining the exposure to risk factors for giardiasis, related to recreational water and drinking water, in ITRCs compared to CCs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variable	OR	95% CI	*P* value
Consumed untreated water	Consumed untreated water			
	Unexposed	Referent		
	Exposed	3·83	2·13–6·87	<0·001
	Age (years)			
	0–8	Referent		
	9–27	0·82	0·39–1·72	0·60
	28–43	0·50	0·24–1·01	0·056
	⩾44	0·82	0·40–1·65	0·57
	Gender			
	Female	Referent		
	Male	0·85	0·40–1·65	0·57
Swam in a pool	Swimming in a pool			
	Unexposed	Referent		
	Exposed	0·79	0·25–2·44	0·69
	Age (years)			
	0–8	Referent		
	9–27	1·03	0·55–1·90	0·94
	28–43	0·41	0·20–0·81	0·01
	⩾44	0·57	0·30–1·10	0·095
	Pool × age 0–8 yr	Referent		
	Pool × age 9–27 yr	1·50	0·32–7·12	0·61
	Pool × age 28–43 yr	4·87	1·12–21·14	0·035
	Pool × age ⩾44 yr	7·95	1·49–42·23	0·015
	Gender			
	Female	Referent		
	Male	0·75	0·49–1·15	0·19
Swam in an ocean	Swimming in an ocean			
	Unexposed	Referent		
	Exposed	32·50	9·71–109·05	<0·001
	Age (years)			
	0–8	Referent		
	9–27	1·01	0·56–1·83	0·96
	28–43	0·43	0·22–0·82	0·011
	⩾44	0·57	0·30–1·09	0·087
	Gender			
	Female	Referent		
	Male	0·82	0·52–1·30	0·40

ITRC, International travel-related case; CC, Canadian case; OR, Odds ratio; CI, confidence interval.

Age

The greatest number of reported CCs were in people aged 28–43 years (Fig. 5). Similarly, the greatest numbers of reported cases also occurred in this age group when CCs were analysed separately as DTRCs and ECs (Fig. 6). By contrast, the fewest numbers of ITRCs occurred in this age group, whereas most occurred in the 0–8 years age group (Figs 5 and 6). In several models, 28- to 43-year-olds were significantly less likely to be ITRCs compared to ECs or CCs (Tables 1–3, 5, 6). Age was found to interact with swimming in a pool for the multivariable logistic regression model, but not for the multinomial regression model (Table 2). Cases aged ⩾28 years that swam in a pool were significantly more likely to be an ITRC than a CC compared to people in the same age groups that did not swim in a pool (Table 8).

DISCUSSION

Although the association between international travel and GI illness has been well documented, there exists

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Table 3. *Statistically significant multivariable logistic regression analyses examining the exposure to risk factors for giardiasis, related to consumption of food, in ITRCs compared to CCs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variable	OR	95% CI	*P* value
Ate food purchased from a food vendor	Food vendor			
	Unexposed	Referent		
	Exposed	3·24	1·22–8·60	0·018
	Age (years)			
	0–8	Referent		
	9–27	0·99	0·55–1·80	0·99
	28–43	0·45	0·24–0·88	0·019
	⩾44	0·61	0·33–1·16	0·13
	Gender			
	Female	Referent		
	Male	0·70	0·44–1·10	0·12
Attended a social gathering where food was served	Ate food at a social gathering			
	Unexposed	Referent		
	Exposed	1·79	1·07–2·99	0·026
	Age (years)			
	0–8	Referent		
	9–27	0·88	0·46–1·67	0·70
	28–43	0·53	0·28–0·97	0·041
	⩾44	0·79	0·43–1·44	0·45
	Gender			
	Female	Referent		
	Male	0·92	0·59–1·44	0·73

ITRC, International travel-related case; CC, Canadian case; OR, Odds ratio; CI, confidence interval.

a significant gap in the literature pertaining to enteric infections acquired while travelling domestically. Current travel research focuses on risk factors such as location and duration of stay, reason for travel, and acquisition of pre-travel health advice [4, 22, 23]. However, there is a lack of knowledge surrounding activities which may increase the risk of enteric infections in both international and domestic travellers. Therefore, this analysis of the exposures to various risk factors for giardiasis cases in the ROW demonstrates that travel-related (domestic and international) cases and ECs have differing levels of risk behaviours associated with these activities. Both types of travel cases were more likely to go camping or kayaking, and consume untreated water, compared to ECs. DTRCs were more likely to visit a petting zoo or farm compared to ECs, and were more likely to go swimming in fresh water (e.g. river or lake) compared to ECs and ITRCs. International travellers were more likely to swim in an ocean compared to both DTRCs and ECs. These differences are important for targeting health promotion programmes for the prevention of giardiasis.

In previous studies, the percentage of reported giardiasis or GI illness cases attributable to international travel ranged from approximately 20–50% in developed countries (e.g. the United States [24], New Zealand [25], Germany [26]). Our findings are similar, as 40% of giardiasis cases in this study were attributable to international travel. Previous studies have identified South Asia, South and Central America, Africa, the Middle East and the Caribbean as regions of high risk for contracting a GI illness [2, 6, 24, 27]. Similarly, the majority ITRCs in our study reported travel to destinations in South Asia, the Caribbean, South America, and sub-Saharan Africa. However, without knowledge of a proper denominator (i.e. the number of travellers to these regions from the ROW), we are unable to determine if these are high-risk areas for contracting a *Giardia* infection, or just common travel destinations for the residents of the ROW. Travel destinations were not recorded for DTRCs in this study. However, in the future, it would be worthwhile to examine if exposure to risk factors for giardiasis are different for different types of domestic travel (e.g. within-province, *vs.* out of province).

Animals, including wildlife and livestock, can shed high numbers of *Giardia* cysts in their faeces and

Table 4. *Descriptive statistics, including percentage of missing observations, number of observations available for multinomial regression analyses and percentage of respondents with exposure to each risk factor for giardiasis for each outcome category for giardiasis cases reported from the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Variable	Outcome category	% Missing observations	*N**	% of respondents with exposure to risk factor
Environmental exposure				
Owns a cat	Endemic	24·6	190	13·2
	Domestic	13·8	25	40·0
	International	18·8	155	9·7
Owns a dog	Endemic	23·4	193	24·9
	Domestic	6·9	27	44·4
	International	17·8	156	23·7
Owns a bird	Endemic	25·0	189	3·2
	Domestic	13·8	25	0
	International	19·9	153	2·7
Owns a reptile	Endemic	24·6	190	2·6
	Domestic	13·8	25	8·0
	International	20·4	152	0
Contact with manure	Endemic	33·7	167	15·0
	Domestic	0·0	29	24·1
	International	19·9	153	3·9
Visited a farm or petting zoo	Endemic	34·9	164	9·1
	Domestic	0·03	28	21·4
	International	19·9	153	13·7
Went kayaking, canoeing or camping	Endemic	32·9	169	2·8
	Domestic	6·9	27	3·4
	International	19·9	153	17·0
Water exposure				
Swam in a hot tub	Endemic	22·6	195	4·1
	Domestic	6·9	27	7·4
	International	17·8	157	8·3
Swam in a pool	Endemic	22·6	195	12·8
	Domestic	6·9	27	14·8
	International	17·2	158	25·9
Swam in the ocean	Endemic	22·6	195	1·0
	Domestic	6·9	27	3·7
	International	17·2	158	27·2
Swam in a river	Endemic	22·6	195	3·1
	Domestic	10·3	26	23·1
	International	17·8	157	7·6
Swam in a lake	Endemic	22·6	195	8·7
	Domestic	6·9	27	44·4
	International	18·3	156	8·3
Drank untreated water	Endemic	42·1	146	11·0
	Domestic	10·3	26	30·8
	International	39·3	116	37·9
Food exposure				
Attended a social gathering with food	Endemic	34·5	165	12·7
	Domestic	0	29	20·7
	International	24·6	144	29·2
Ate meat not purchased at a grocery store	Endemic	33·0	128	28·9
	Domestic	10·3	26	11·5
	International	33·0	128	28·9
Unpasteurized milk	Endemic	27·0	184	2·7
	Domestic	10·3	26	0·0
	International	26·7	140	5·0

Table 4 (*cont.*)

Variable	Outcome category	% Missing observations	N*	% of respondents with exposure to risk factor
Unpasteurized juice	Endemic	27·0	184	0·5
	Domestic	10·3	26	0·0
	International	26·7	140	1·4
Ate at a restaurant	Endemic	26·7	140	40·0
	Domestic	17·2	24	66·7
	International	26·7	140	40·0
Ate at a food vendor	Endemic	33·7	167	3·6
	Domestic	17·2	24	4·2
	International	27·7	138	9·4
Ate food from a delicatessen	Endemic	33·7	167	1·8
	Domestic	17·2	24	16·7
	International	27·2	139	2·9
Ate fast food	Endemic	33·3	168	14·3
	Domestic	17·2	24	33·3
	International	28·3	137	14·6
Ate food from a cafeteria	Endemic	33·3	168	3·0
	Domestic	17·2	24	16·7
	International	27·2	139	8·6

* N represents the number of observations available for analysis.

contaminate the surrounding environment where humans may become exposed [28–33]. As such, DTRCs were more likely to be exposed to manure or organic fertilizer compared to ECs and ITRCs. Similarly, visiting a petting zoo was also more common for DTRCs compared to ECs and ITRCs. These results suggest that DTRCs are more likely to be exposed to livestock than cases acquired endemically or abroad. This suggests that the nature of travel activities is different for DTRCs, and includes more rural and agricultural related activities.

Recreational water exposure, such as swimming in lakes and rivers, has frequently been associated with enteric diseases, especially when contaminated surface water is consumed during these activities [10, 15, 25, 34, 35]. Surface waters may become contaminated during extreme weather events and when human activity increases during favourable weather conditions [9]. Exposure to recreational fresh water bodies (e.g. rivers and lakes) is significantly more common in DTRCs compared to both ECs and ITRCs. By contrast, ITRCs have greater exposures to swimming in salt water (e.g. the ocean) or a pool, compared to ECs. This difference in exposures to different types of recreational waters is likely due to the nature of travel, and the availability of these water sources to travellers. For example, fresh water bodies (e.g. river, lake) surround domestic travellers, especially those who camp or visit cottages, whereas Canadians often travel internationally to tropical destinations and are frequently in close proximity to an ocean. These findings suggest that the nature of recreational water use differs in DTRCs and ITRCs, and includes swimming in different types of water, which may pose different levels of risk for infection with *Giardia.*

The relationship between drinking untreated water and GI illness has been thoroughly documented throughout the literature, for both ITRCs and ECs of GI illness [36–38]. In particular, drinking non-municipal water outside the country of residence has been identified as a significant risk factor for giardiasis [25]. Exposure to untreated drinking water was significantly more common in travel-related (both international and domestic) cases compared to ECs in the ROW. It is possible that travellers have less access to treated drinking water than they would at home, leading to this difference in exposure. For cases who were visiting friends and relatives (VFRs), it is also probable that they would drink water from the same source as their friends and relatives, regardless of treatment, and may not perceive a risk in consuming the same water. It is also a possibility that travellers are unaware of where their water comes from and they may assume it is treated, depending on their travel destination, and may underestimate their exposure to untreated water. Validating these fields in the

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Table 5. *Statistically significant multivariable multinomial logistic regression analyses examining the exposure to companion animal and environmental risk factors for giardiasis for DTRCs and ITRCs relative to ECs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variables	Outcome category	OR*	95% CI	*P* value
Cat	Owns a cat			1·68–10·64	
	Unexposed		Referent		
	Exposed	Domestic	4·23	1·68–10·64	0·002
		International	0·71	0·36–1·40	0·33
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·91	0·33–11·4	0·47
		International	1·22	0·63–2·16	0·51
	28–43	Domestic	4·39	0·88–21·70	0·07
		International	0·76	0·41–1·39	0·37
	⩾44	Domestic	5·31	1·09–25·95	0·039
		International	0·85	0·46–1·55	0·59
	Gender				
	Female		Referent		
	Male	Domestic	1·31	0·53–3·23	0·55
		Endemic	0·81	0·53–1·25	0·34
Petting zoo or farm	Visited a zoo				
	Unexposed		Referent		
	Exposed	Domestic	3·17	1·08–9·36	0·036
		International	1·60	0·79–3·24	0·19
	Age (years)				
	0–8		Referent		
	9–27	Domestic	2·05	0·35–12·02	0·43
		International	1·01	0·53–1·93	0·97
	28–43	Domestic	4·43	0·92–21·38	0·064
		International	0·66	0·36–1·22	0·19
	⩾44	Domestic	5·55	1·14–26·92	0·033
		International	0·98	0·53–1·83	0·96
	Gender				
	Female		Referent		
	Male	Domestic	1·73	0·72–4·15	0·22
		International	0·91	0·58–1·43	0·68
Camping, kayaking or canoeing	Participated in camping, kayaking or canoeing				
	Unexposed		Referent		
	Exposed	Domestic	13·61	4·04–42·02	<0·001
		International	5·27	2·18–12·77	<0·001
	Age (years)				
	0–8		Referent		
	9–27	Domestic	2·02	0·19–21·29	0·56
		International	0·84	0·43–1·63	0·61
	28–43	Domestic	6·67	0·81–54·81	0·077
		International	0·56	0·30–1·05	0·072
	⩾44	Domestic	9·11	1·11–74·85	0·040
		International	0·98	0·53–1·81	0·95
	Gender				
	Female		Referent		
	Male	Domestic	1·21	0·50–2·94	0·67
		International	0·88	0·56–1·39	0·59
Contact with manure or organic fertilizer	Contact with manure/fertilizer				
	Unexposed		Referent		
	Exposed	Domestic	1·39	0·52–3·75	0·52
		International	0·23	0·09–0·59	0·002

Table 5 (*cont.*)

Exposure model	Variables	Outcome category	OR*	95% CI	*P* value
	Age (years)				
	0–8		Referent		
	9–27	Domestic	2·37	0·41–13·73	0·34
		International	1·08	0·57–2·05	0·81
	28–43	Domestic	4·75	0·99–22·82	0·052
		International	0·82	0·44–1·53	0·54
	⩾44	Domestic	5·30	1·08–25·91	0·039
		International	1·22	0·65–2·28	0·54
	Gender				
	Female		Referent		
	Male	Domestic	1·56	0·67–3·61	0·30
		International	0·88	0·56–1·39	0·59
Season	Season				
	Winter		Referent		
	Spring	Domestic	0·81	0·17–3·88	0·80
		International	1·31	0·27–6·26	0·74
	Summer	Domestic	0·46	0·12–1·78	0·26
		International	0·36	0·09–1·44	0·15
	Autumn	Domestic	0·30	0·079–1·15	0·079
		International	0·25	0·065–0·99	0·048
	Age (years)				
	0–8	Referent			
	9–27	Domestic	0·52	0·092–2·97	0·47
		International	0·54	0·093–3·08	0·49
	28–43	Domestic	0·21	0·046–0·99	0·05
		International	0·13	0·026–0·61	0·010
	⩾44	Domestic	0·16	0·033–0·75	0·021
		International	0·15	0·031–0·722	0·018
	Gender				
	Female		Referent		
	Male	Domestic	0·72	0·32–1·65	0·44
		International	0·64	0·28–1·50	0·31

DTRC, Domestic travel-related case; ITRC, international travel-related case; EC, endemic case; OR, Odds ratio; CI, confidence interval.
* Some researchers refer to this as a relative risk ratio instead of an odds ratio.

questionnaire may have practical implications for future studies and disease prevention.

Enteric disease outbreaks due to improper food safety in restaurants have been well documented in both developed and developing nations [39, 40]. Exposure to foods prepared at a restaurant, delicatessen or cafeteria were significantly more common in DTRCs compared to ECs, and exposure to delicatessen foods was also more common in DTRCs compared to ITRCs. However, exposure to these types of foods was not significantly different in ITRCs and ECs. It is possible that this difference in exposure is due to the method of travel (e.g. by car) for domestic travellers, where they may be more likely to stop for food at a restaurant or similar place during long trips. It is also likely that travellers have less access to facilities to prepare their own food, especially if they are staying in a hotel without a kitchen, making them more likely to visit a restaurant. As parasitic infections, such as giardiasis, in international travellers have been related to longer travel durations [27], it is likely that for these extended trips, travellers would likely have access to cooking facilities, thus making their exposure to ready-made foods similar to ECs. It is also possible that a proportion of the ITRCs are VFRs and would therefore likely consume more meals prepared by their friends and relatives compared to ready-to-eat foods during their visit. Improved follow-up should be implemented for the questions pertaining to reason for travel, as there are likely differences in exposure to risk factors for giardiasis in different types of travellers (e.g. VFRs,

Table 6. *Statistically significant multivariable multinomial logistic regression analyses examining the exposure to risk factors, related to recreational water and drinking water, for DTRCs and ITRCs relative to ECs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variables	Outcome category	OR*	95% CI	*P* value
Swam in a river	Swam in a river				
	Unexposed		Referent		
	Exposed	Domestic	10·15	2·81–36·55	<0·001
		International	2·92	1·05–8·10	0·039
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·35	0·21–8·62	0·75
		International	1·09	0·61–1·94	0·73
	28–43	Domestic	4·03	0·82–19·77	0·086
		International	0·65	0·36–1·20	0·17
	⩾44	Domestic	6·76	1·40–32·65	0·017
		International	1·00	0·55–1·83	0·99
	Gender				
	Female		Referent		
	Male	Domestic	0·92	0·38–2·22	0·85
		International	0·73	0·47–1·12	0·15
Swam in a lake	Swam in a lake				
	Unexposed		Referent		
	Exposed	Domestic	8·09	3·12–21·03	<0·001
		International	1·03	0·47–2·23	0·935
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·15	0·18–7·48	0·88
		International	1·14	0·64–2·03	0·65
	28–43	Domestic	3·56	0·71–17·69	0·12
		International	0·66	0·36–1·22	0·19
	⩾44	Domestic	5·99	1·21–29·15	0·028
		International	1·00	0·55–1·83	0·99
	Gender				
	Female		Referent		
	Male	Domestic	1·02	0·42–2·49	0·99
		International	0·75	0·49–1·16	0·20
Swam in an ocean	Swam in an ocean				
	Unexposed		Referent		
	Exposed	Domestic	2·76	0·24–31·89	0·41
		International	41·20	9·67–175·35	<0·001
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·61	0·26–10·10	0·61
		International	1·03	0·57–1·88	0·91
	28–43	Domestic	5·29	1·12–25·09	0·036
		International	0·50	0·25–0·97	0·039
	⩾44	Domestic	6·67	1·40–31·84	0·017
		International	0·69	0·36–1·34	0·28
	Gender				
	Female		Referent		
	Male	Domestic	1·13	0·48–2·63	0·78
		International	0·83	0·52–1·33	0·44
Swam in a pool	Swam in a pool				
	Unexposed		Referent		
	Exposed	Domestic	0·91	0·28–2·86	0·87
		International	2·23	1·229–3·85	0·004

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Table 6 (*cont*.)

Exposure model	Variables	Outcome category	OR*	95% CI	*P* value
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·62	0·26–10·12	0·61
		International	1·10	0·62–1·98	0·73
	28–43	Domestic	5·45	1·15–29·91	0·033
		International	0·65	0·36–1·20	0·17
	⩾44	Domestic	6·85	1·44–32·64	0·016
		International	0·98	0·53–1·80	0·95
	Gender				
	Female		Referent		
	Male	Domestic	1·13	0·48–2·63	0·77
		International	0·75	0·50–1·16	0·20
Drank untreated water	Untreated water				
	Unexposed		Referent		
	Exposed	Domestic	4·05	1·47–11·09	0·007
		International	5·19	2·70–9·97	<0·001
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·73	0·29–10·32	0·55
		International	0·92	0·43–1·98	0·83
	28–43	Domestic	3·93	0·80–19·31	0·092
		International	0·64	0·30–1·34	0·24
	⩾44	Domestic	4·07	0·81–20·53	0·09
		International	1·05	0·51–2·18	0·89
	Gender				
	Female		Referent		
	Male	Domestic	1·50	0·62–3·65	0·37
		International	0·88	0·52–1·49	0·64

DTRC, Domestic travel-related case; ITRC, international travel-related case; EC, endemic case; OR, Odds ratio; CI, confidence interval.
* Some researchers refer to this as a relative risk ratio instead of an odds ratio.

pleasure, business, immigrant). These results therefore suggest that the nature of exposure to prepared foods is different for domestic travel compared to other types of cases.

Traditionally, DTRCs and ECs are grouped together into a domestic category (e.g. Canadian acquired) in studies that examine the effect of travel on the burden of illness in a population. To the best of the authors' knowledge, this is the first study to separate CCs into ECs and DTRCs, instead of this traditional method. However, the results from our multinomial regression analyses must be interpreted with caution due to the small number of DTRCs available for analysis ($n = 29$). There were differences in exposures to risk factors when the traditional grouping was compared to separation of the CCs into DTRCs and ECs. Significant risk factors identified in the multinomial regression that allowed for separation of DTRCs and ECs included: having a pet cat, visiting a petting zoo, swimming in a river or lake, and eating food prepared at a delicatessen, cafeteria or restaurant. However, exposure to attending a social function or consuming food from a food vendor was only found to be significantly different in ITRCs compared to CCs (i.e. when domestic travel and ECs were included together). An interaction was also found between swimming in a pool and age when all CCs were included together, but this effect was not noted when DTRCs and ECs were analysed separately. As significant differences in exposure to various risk factors for giardiasis were identified between DTRCs and ECs when analysed separately, this suggests that for future studies, DTRCs and ECs should not be included together as this may result in missing important associations or risk factors.

In our study, we used a case-case study design, as our interest was the relative differences in exposures to risk factors for giardiasis cases in ITRCs, DTRCs

Table 7. *Statistically significant multivariable multinomial logistic regression analyses examining the exposure to risk factors, related to food consumption, for DTRCs and ITRCs relative to ECs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Exposure model	Variables	Outcome category	OR*	95% CI	*P* value
Ate in a cafeteria	Cafeteria food				
	Unexposed		Referent		
	Exposed	Domestic	5·41	1·30–22·59	0·021
		International	3·87	1·29–11·58	0·015
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·89	0·33–10·91	0·48
		International	1·05	0·58–1·91	0·88
	28–43	Domestic	3·53	0·70–17·93	0·13
		International	0·49	0·25–0·97	0·041
	⩾44	Domestic	5·31	1·09–26·0	0·039
		International	0·77	0·40–1·45	0·43
	Gender				
	Female		Referent		
	Male	Domestic	1·02	0·41–2·54	0·96
		Endemic	0·74	0·46–1·18	0·20
Ate food from a delicatessen	Delicatessen food				
	Unexposed		Referent		
	Exposed	Domestic	10·83	2·10–55·91	0·004
		International	1·78	0·38–8·34	0·46
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·51	0·25–9·05	0·65
		International	1·05	0·58–1·92	0·86
	28–43	Domestic	3·30	0·64–16·90	0·15
		International	0·54	0·27–1·05	0·07
	⩾44	Domestic	5·38	1·10–26·38	0·038
		International	0·83	0·44–1·58	0·58
	Gender				
	Female		Referent		
	Male	Domestic	1·00	0·40–2·53	0·99
		International	0·79	0·50–1·26	0·32
Ate food from a restaurant	Restaurant food				
	Unexposed		Referent		
	Exposed	Domestic	5·31	2·01–13·98	0·001
		International	2·87	1·67–4·93	<0·001
	Age (years)				
	0–8		Referent		
	9–27	Domestic	1·34	0·22–7·99	0·75
		International	0·88	0·48–1·63	0·68
	28–43	Domestic	2·02	0·37–10·95	0·41
		International	0·37	0·18–0·77	0·007
	⩾44	Domestic	3·01	0·58–15·71	0·19
		International	0·56	0·28–1·11	0·097
	Gender				
	Female		Referent		
	Male	Domestic	1·02	0·44–2·75	0·83
		International	0·75	0·47–1·19	0·22

DTRC, Domestic travel-related case; ITRC, international travel-related case; EC, endemic case; OR, Odds ratio; CI, confidence interval.
* Some researchers refer to this as a relative risk ratio instead of an odds ratio.

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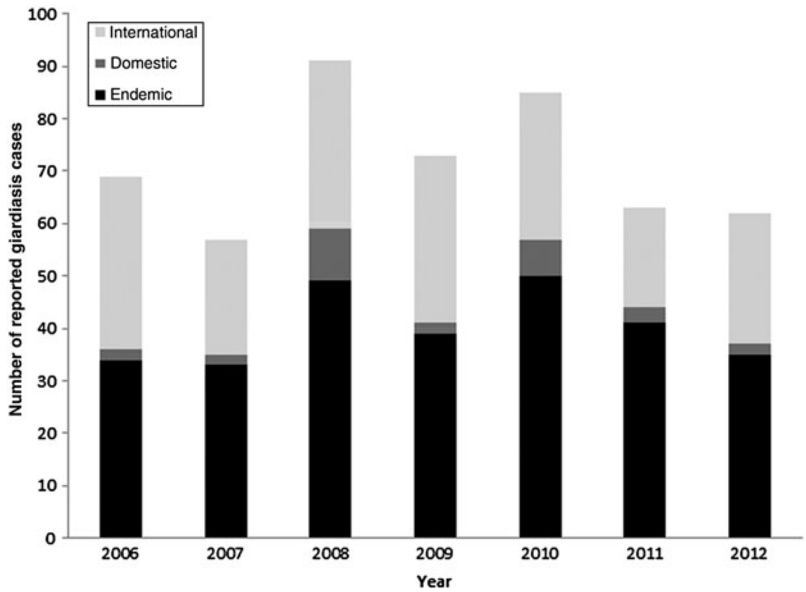

Fig. 3. Number of giardiasis cases reported to the FoodNet Canada programme sentinel site in the Region of Waterloo per year from 2006 to 2012 for international travel-related cases, domestic travel-related cases, and endemic cases.

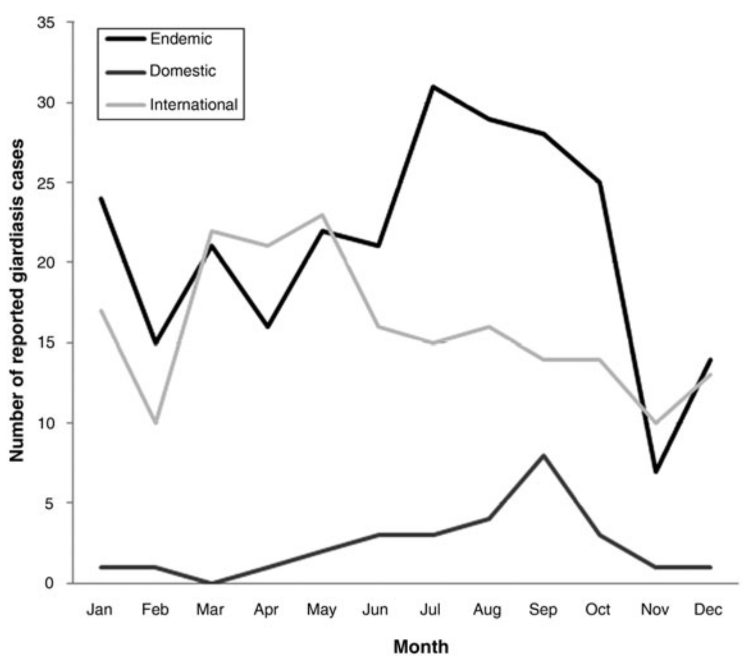

Fig. 4. The sum of reported giardiasis cases per month from the Region of Waterloo FoodNet Canada sentinel site from 2006 to 2012 for international travel-related cases, domestic travel-related cases, and endemic cases.

and CCs. This study design has previously been recommended for identifying risk factors for diseases from an ongoing surveillance system for focused subsets of disease, such as FoodNet Canada [21]. A case-control study design is a possible alternative to the case-case design. However, picking appropriate controls would be difficult as only enteric infections are reported to FoodNet Canada, and other cases would share similar exposures with giardiasis cases. A longitudinal study examining the rates of giardiasis would be another possible alternative study design, but there is an absence of an appropriate denominator as there are no available data concerning the number of residents travelling either domestically or internationally.

It is important to consider potential recall and misclassification biases when interpreting the results of

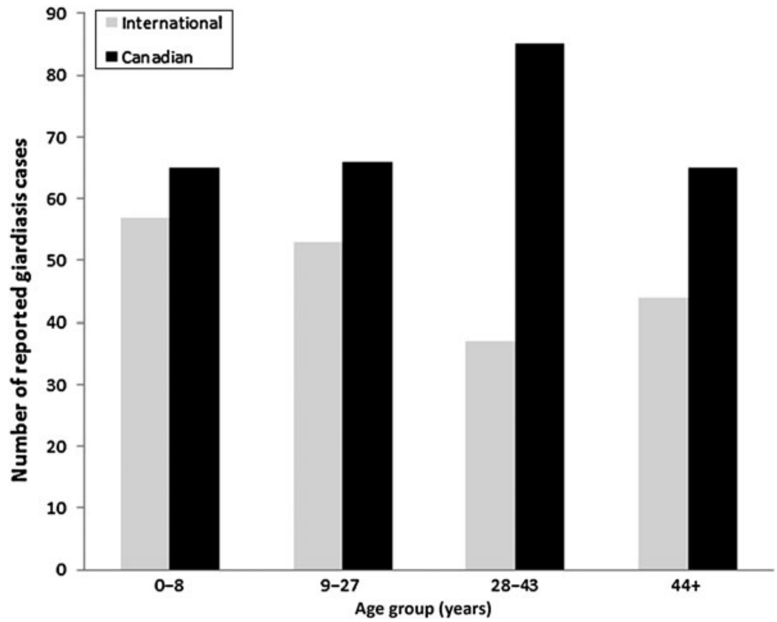

Fig. 5. The number of reported giardiasis cases per age group from the Region of Waterloo FoodNet Canada sentinel site from 2006 to 2012 for international travel-related cases, domestic travel-related cases, and endemic cases.

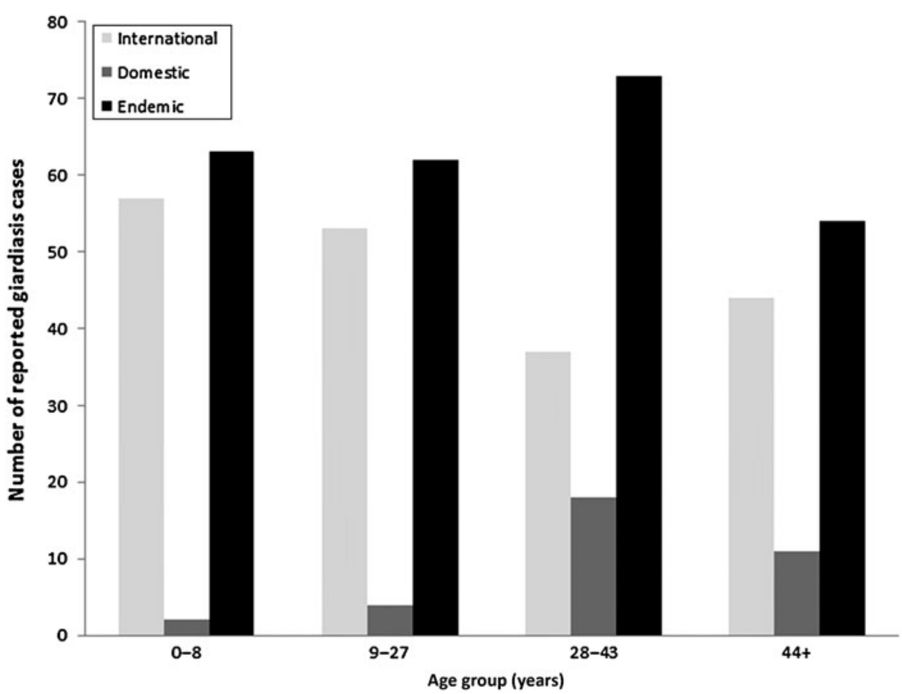

Fig. 6. The sum of reported giardiasis cases per age group from the Region of Waterloo FoodNet Canada sentinel site from 2006 to 2012 for international travel-related cases, domestic travel-related cases, and endemic cases.

our study. First, recall bias is a possible concern due to the relatively long incubation period (up to 21 days) of giardiasis [41]. It is quite likely that cases would not remember possible exposures, which would result in false negative answers to exposure questions. Furthermore, individuals who have an increased awareness of the possible health risks associated with travelling may be more likely to recall certain risky exposures, compared to individuals unaware of travelling risks, leading to differential misclassification

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Table 8. *Contrast statements for the interaction between age and pool, when swimming in a pool vs. not swimming a pool was compared between age groups, from the multivariable logistic regression model for giardiasis in ITRCs compared to CCs, reported to the FoodNet Canada Region of Waterloo sentinel site from 2006 to 2012*

Contrast	OR	95% CI	*P* value
Age 0–8 yr, Pool *vs.* no pool	0·79	0·26–2·45	0·69
Age 9–27 yr, Pool *vs.* no pool	1·19	0·41–3·50	0·75
Age 28–43 yr, Pool *vs.* no pool	3·86	1·50–9·96	0·005
Age ⩾43 yr, Pool *vs.* no pool	6·31	1·83–21·73	0·003

ITRC, International travel-related case; CC, Canadian case; OR, Odds ratio; CI, confidence interval.

bias. Second, the long and variable incubation period of giardiasis can also complicate the classification of case type (e.g. endemic *vs.* travel-related) and lead to misclassification. Therefore, it would be difficult to discern where cases had become infected if they had travelled both internationally and domestically during the same trip. Likewise, if someone was travelling internationally for a short period (e.g. travelling to the United States for a few days) they would be classified as an ITRC; however, they may have not been exposed while traveling. It is also important to understand that different travel destinations and reasons for international travel likely result in different risks for giardiasis. For example, a day trip to the United States for shopping would likely have a lower risk for contracting giardiasis compared to backpacking in a developing country.

When interpreting the results of our study, it is also important to note that it was unknown if cases were a single infection, or a coinfection with other pathogens. It is currently difficult to capture co-infections in surveillance systems. Generally, this is due to the diagnostic laboratories not continuing to search for subsequent pathogens once they have diagnosed the first. This represents a possible gap in knowledge, as previous studies from developing countries have demonstrated that the presence of other pathogens such as *Heliobacter pylori, Vibrio cholerae* and rotavirus have been associated with *Giardia* co-infection [42–44]. Research on the prevalence of coinfections in returned travellers and whether identifying these co-infections is practical may be warranted in the future.

In our study, we examined potential differences in exposures to risk factors for giardiasis in cases with varying travel histories. Of the reported giardiasis cases, 40% had travelled internationally and the most commonly reported international destinations were India, Pakistan, Bangladesh and Cuba. International travel related cases had significantly different exposures to risk factors for giardiasis compared to DTRCs and ECs. In particular, ITRCs were significantly more likely to swim in an ocean compared to DTRCs and were more likely to go camping/kayaking/canoeing, swim in a river/ocean/pool, or drink untreated water compared to ECs. This suggests that international travellers exhibit different risk behaviours while they are travelling internationally compared to while they are at home. As previously indicated, this is the first study to explore separating DTRCs and ECs instead of collapsing them together into a CC group. We found that there were significant differences in exposures to various risk factors for giardiasis in the various case groups, including significant differences between ECs and DTRCs. In particular, DTRCs were significantly more likely to own a cat, visit a petting zoo, go camping/kayaking/canoeing, swim in fresh water, drink untreated water or eat food from a cafeteria/delicatessen/restaurant compared to ECs. This therefore suggests that collapsing these cases together into one category may not be appropriate. Current risk assessment and source attribution methods use the traditional method of collapsing ECs and DTRCs together. However, it is important to distinguish between these two case types as the exposures to various risk factors for giardiasis varies in these groups, and may have an impact on public health policies. Perhaps of greater significance, our findings are important for creating effective and targeted health promotion campaigns to prevent giardiasis in this region, by targeting activity-specific (e.g. endemic, domestic or international travel) risk activities.

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DECLARATION OF INTEREST

None.

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