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People, Pets, and Parasites: One Health Surveillance in Southeastern Saskatchewan

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Abstract. Residents of remote and Indigenous communities might experience higher exposure to some zoonotic parasites than the general North American population. Human sero-surveillance conducted in two Saulteaux communities found 113 volunteers exposed as follows: *Trichinella* (2.7%), *Toxocara canis* (4.4%), *Echinococcus* (4.4%), and *Toxoplasma gondii* (1.8%). In dogs, 41% of 51 fecal samples were positive for at least one intestinal parasite, 3% of 77 were sero-positive for *Borrelia burgdorferi*, and 21% of 78 for *T. gondii*. *Echinococcus* exposure was more likely to occur in non-dog owners (odds ratio [OR]: 11.4, 95% confidence interval [CI]: 1.2–107, $P = 0.03$); while *T. canis* was more likely to occur in children (ages 4–17) (OR: 49, 95% CI: 3.9–624; $P = 0.003$), and those with a history of dog bites (OR: 13.5, 95% CI: 1.02–179; $P = 0.048$). Our results emphasize the use of dogs as sentinels for emerging pathogens such as Lyme disease, and the need for targeted surveillance and intervention programs tailored for parasite species, cultural groups, and communities.

INTRODUCTION

Zoonotic parasites are ubiquitous, and challenge public health systems in both urban and rural environments, even within developed countries in North America. Waterborne outbreaks of *Cryptosporidium*, *Giardia*, and *Toxoplasma gondii* have all occurred in Canadian cities in recent years, accompanied by extensive public health messaging to help protect urban residents.[1,2] As compared with urban residents, rural, remote, and northern residents may encounter parasites more frequently, and by mechanisms that are covert, as a result of alternative water sources, reliance on wild game/fish, and closer relationships with wildlife, livestock, and the land. Consumption of undercooked or raw meat by people has been linked to food-borne outbreaks, including trichinellosis in northern Saskatchewan and toxoplasmosis in northern Quebec.[3,4] Companion animals, dogs in particular, can facilitate zoonotic transmission of parasites by acting as a source of infection for people, and as a bridge between wildlife and people. *Echinococcus* and *Toxocara* spp. are two such examples, and are acquired by people through accidental ingestion of eggs shed in dog feces. On the other hand, surveillance of dogs can play a critical role in preventing human illness, serving as sentinels for infection when they are exposed at higher levels and earlier than people during vector range expansion, or disease emergence in a region.

Indigenous peoples of Canada are reported to be at higher risk of exposure to some zoonotic parasites than non-Indigenous peoples, with potentially life-threatening consequences.[5–7] Seropositivity is an indicator of exposure to a pathogen, and requires diagnostic follow-up testing to determine if an individual is actively infected. Some zoonoses, such as echinococcosis and toxocariasis, are likely under-detected and under-reported because of non-specific or asymptomatic case presentation, imperfect detection methods, and the prolonged period between infection and illness. Because most Canadian sero-prevalence studies are conducted in northern and/or remote Indigenous communities, sparse information is available for the general Canadian population or for southern Indigenous groups, even though the risk factors for parasite exposure may be similar. Saulteaux Ojibway reside in communities scattered across British Columbia, Alberta, Saskatchewan, Manitoba, and Ontario. This project was conducted in collaboration with two Saulteaux Treaty 4 communities in southeastern Saskatchewan, where country foods are frequently consumed, even though the residents live within a 1 hour driving distance of an urban center (~100 km). The goal of this work is to explore levels of human and canine exposure to parasites in a southern, rural, and Indigenous area of Saskatchewan. We chose to measure human exposure to *Trichinella*, *Toxoplasma gondii*, *Echinococcus*, and *Toxocara canis*, as these pathogens have been studied in several other Canadian Indigenous communities, and offer a good basis for comparison.

MATERIALS AND METHODS

Human participants. This study was conducted in collaboration with members of two neighboring Saulteaux communities located geographically in the Sunrise Health Region of southeastern Saskatchewan. These rural communities house ~423 and 757 residents, and are surrounded by agricultural lands used primarily for cash crop farming.[8] Planning and implementation of this project occurred in collaboration with key community members at a community camp-out and while working together on a digital storytelling project. We recruited participants > 4 years of age by word of mouth and by posters displayed in community gathering spaces. Sample collection occurred during two community events: 1) a low-cost pet health clinic organized by the research team, and 2) the annual Treaty Days celebration.

Human serology and risk factor assessment. Each adult participant first completed a survey pertaining to risk factors for parasite exposure, including dietary habits, pet ownership, use of veterinary services, history of dog bites, and hunting practices. Parents were asked to complete surveys on behalf of their children. Approximately 3–5 mL of blood was then collected from each participant into serum separator tubes (BD, Franklin Lakes, NJ) and refrigerated overnight. Samples were centrifuged at 3,500 rpm for 10 minutes, and sera

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TABLE 1
Criteria for serological evaluation of four zoonotic parasites and results of sero-surveillance in two Saulteaux communities in southeastern Saskatchewan ($N = 113$)

Parasite	Measurement	Criteria and results		
		Negative	Equivocal	Positive
Toxocara canis	Optical density	< 0.25	0.25–0.35	> 0.35
Number samples		106	2	5
Trichinella	Optical density	< 0.25	0.25–0.35	> 0.35
Number samples		106	4	3
Echinococcus granulosus	Optical density	< 0.35	0.35–0.45	> 0.45
Number samples		107	1	5
Toxoplasma gondii	Units IgG (IU/mL)	< 1	NA	≥ 1
Number samples		111	NA	2

were pipetted into snap-top micro-centrifuge tubes. Sera were frozen at −20°C until transported to the National Reference Center for Parasitology (McGill University, Montreal, QC) and analyzed by in-house and IVD Research (Carlsbad, CA) developed enzyme-linked immunosorbent assays (ELISA) for immunoglobulin G antibodies against *Echinococcus*, *Toxocara canis*, *Trichinella*, and *Toxoplasma gondii*. The ELISA results were interpreted according to criteria in Table 1, with equivocal results treated as negative.

Canine serology. Blood samples were collected from dogs at their homes in November 2011 ($N = 32$), and again in November 2012 ($N = 46$) from dogs brought to a remote service veterinary clinic. If the dog became unduly stressed or fractious, we discontinued sampling. A standard veterinary history intake form was filled out for each animal brought to the remote clinic, including age, gender, vaccination and deworming history, and observations of ectoparasites. Approximately 3 mL of blood was collected from each dog into serum separator tubes, and samples were kept on ice during transport to the University of Saskatchewan. Tubes were spun at 3,500 rpm for 10 minutes and sera were frozen at −20°C. Exposure to *T. gondii* was determined using an indirect fluorescent antibody test (IFAT; VMRD, Pullman, WA) at a serum dilution of 1:50. We evaluated exposure to four vector-borne pathogens (*Dirofilaria immitans*, *Borrelia burgdorferi*, *Anaplasma phagocytophilum*, and *Ehrlichia canis*) using SNAP 4Dx Plus tests (IDEXX Laboratories, Inc., Westbrook, ME) according to manufacturer instructions. Both tests were validated for use in dogs.

Canine fecal surveillance. Canine fecal samples were collected in November 2011 ($N = 25$), and again in June 2013 ($N = 26$) from dog owners' yards and roadways. Only one fecal sample was collected per property to avoid collecting multiple samples from the same dog. Fecal samples were individually bagged, stored on ice, and brought to the University of Saskatchewan Zoonotic Parasite Research Unit for processing. After a 3-day freezing period at −80°C (to inactivate zoonotic *Echinococcus* eggs), samples were analyzed for parasite eggs using a modified double centrifugation and quantitative sucrose Stoll flotation.[9] Briefly, 4 grams wet weight (ww) of each sample was homogenized in 40 mL dH_2O and strained through a single layer of 40–60 weight cheesecloth, using a tongue depressor to squeeze out excess water. A 5 mL sterile syringe (BD) was used to transfer a 10% aliquot of fecal slurry into a 15 mL test tube, which was then filled to the top with dH_2O. Test tubes were centrifuged (1,500 rpm, 10 min) and the supernatant poured off. The pellet was resuspended in Sheather's sucrose flotation solution (spp gravity 1.26) by vortexing (maximum speed), filled to the top with Sheather's, and a coverslip (22 × 22 mm) was applied. After a second period of centrifugation (1,500 rpm, 10 min), the coverslip was placed on a labeled glass slide and viewed under a microscope at 10–40× magnification. Helminth ova and cysts were counted for the entire slide, and used to calculate the total eggs or cysts per gram of feces. An additional sucrose gradient flotation and immunofluorescent assay was used to isolate *Giardia* cysts and *Cryptosporidium* oocysts.[10] Briefly, 2–4 grams feces (ww) were homogenized in 8 mL sterile saline, strained through a double layer of cheesecloth, and transferred onto 5 mL methylene blue sucrose solution (spp gravity 1.13) in a sterile 15 mL Falcon tube (Thermo Fisher Scientific Inc., Waltham, MA). After centrifugation (1,300 rpm, 5 min), the top layer of the sucrose gradient was pipetted into a second 15 mL Falcon tube, and centrifuged again (1,300 rpm, 5 min). The supernatant was poured off, the fecal pellet was resuspended in 1 mL saline solution by vortexing, and 15 μL was pipetted into the well of a fluorescent microscope slide (Thermo Scientific, Portsmouth, NH). The slide was dried at room temperature (30 min), and 20 μL each of Giard-o-Glo and Crypt-o-Glo (Waterborne Inc., New Orleans, LA) were added. After an incubation period (37°C, 45 min), a coverslip was added, and the slide was viewed under a fluorescent microscope (40–100× magnification). Cysts and oocysts were counted for the whole slide, and then used to calculate cysts or oocysts per gram feces.

Ethics. The human component of this project was reviewed and approved by the University of Saskatchewan's Biomedical Research Ethics Board (REB 11-07). Each adult participant provided written informed consent, and those < 18 years of age provided written consent from a parent or guardian before participation. All results were kept confidential, and we informed each individual of their results by mail. We organized a follow-up meeting with community members at the completion of the project to share the results, and to answer outstanding questions. Any person testing positive for exposure to *Echinococcus* and all children who tested positive for *T. canis* were encouraged to seek free follow-up testing with a human health provider. The canine component of this study was reviewed and approved by the University of Saskatchewan Animal Research Ethics Board (2009-0126 and 2010-0159), which adheres to Canadian Council on Animal Care (CCAC) standards. Consent to collect blood from individual dogs was provided by their owners, whereas canine feces around the community were collected with permission from community leaders.

TABLE 2

Subset of study population and risk factor variables examined in two Saulteaux communities

Variable (*N**)	n	%	95% Confidence interval
Female gender (112)	75	66	58–75
Age (112)			
4–10	15	13	8–21
11–17	17	15	10–23
18–35	23	21	14–29
36–50	28	25	18–34
51–65	21	19	13–27
> 65	8	7	4–13
Pet ownership (113)			
Dog (yes)	81	72	63–79
Cat (yes)	34	30	22–39
Veterinary care (87)			
Pet ever de-wormed	44	51	40–61
Pet ever vaccinated	46	53	42–63
Owner uses veterinary services	34	40	30–50
Allow dog to roam (65)	45	69	57–79
Believes dogs cause problems in community (85)	59	69	59–78
Feed raw meat to dog (82)	15	18	11–28
Desexing (86)			
Pet is already desexed	23	27	19–37
Owner is against/unsure about desexing pets	28	33	24–43
Dog bite frequency (89)			
Never	56	63	53–72
Once	18	20	13–30
2–3 times	11	12	7–21
> 3 times	4	4	2–11
Hunt/trap (107)	19	18	12–26
Eat wild meat (109)	82	76	66–82
Cooked	73	67	58–75
Dried	11	10	6–17
Smoked	8	7	4–14
Raw	0	0	0–3.4
Eat wild fish (107)	30	28	20–37
Cooked	28	26	19–35
Dried	4	4	1–9
Smoked	1	1	0.2–5
Raw	1	1	0.2–5

* *N* = number of participants who answered the question.

Statistical methods. Bivariate analysis was used to identify correlations between survey responses and sero-status for individual parasites and overall parasite sero-status, with exposed and not exposed individuals coded as 1 and 0, respectively. Using a cut-off value of $P < 0.2$ to determine statistical significance, correlated variables were included by forward stepwise addition to build binary regression models, using the Likelihood Ratio Test to select the final model (SPSS version 20; IMB Corporation, Armonk, NY). The strength of association between independent variables and sero-status was assessed using an odds ratio (OR) with a 95% confidence interval (CI). All variables were treated as categorical. Confounding was assumed if the inclusion of one risk factor changed the effect estimate of another by more than 10%. A Pearson χ^2 test was used to determine if canine sero-prevalence to *Toxoplasma gondii* was significantly different between the sampling years, using a two-sided cut-off value of $P < 0.05$. The Wilson score interval corrected for population size was used to determine the statistical significance of differences in survey responses (OpenEpi version 3.01; Atlanta, GA).

RESULTS

Human serology and risk factor assessment. The participation rate in these communities was ~11%: 113 volunteers (female $N = 75$; male $N = 38$) of 1,000 residents > 4 years of age (Table 2).[8] Titers above the cut-off value were observed in 12% (13 of 113) of participants for at least one parasite of interest (Tables 1 and 3). Sero-prevalence for individual pathogens was observed as follows: *Echinococcus* 4.4% (5 of 113); *T. canis* 4.4% (5 of 113); *Trichinella* 2.7% (3 of 113); and *T. gondii* 1.8% (2 of 113). Co-exposure to *Echinococcus* and *Trichinella* was observed in 2% (2 of 113) of the study population.

Bivariate analysis identified age ($P = 0.13$), owning a cat ($P = 0.14$), owning a dog ($P = 0.007$), and feeding pets raw meat ($P = 0.007$) as potential risk factors for *Echinococcus* exposure. Potential risk factors for the remaining parasites were as follows: *T. canis*—age ($P = 0.058$) and history of dog bites ($P = 0.007$); *Trichinella*—age ($P = 0.14$), and dog ownership ($P = 0.14$); *T. gondii*—age ($P = 0.13$), and history of not deworming pets ($P = 0.17$). Only one variable was correlated to overall positive sero-status—feeding dogs raw meat ($P = 0.11$). Binary logistic analysis showed that three variables were significantly associated with positive sero-status: 1) non-dog owners were more likely to be exposed to *Echinococcus* than dog owners (OR = 11.4, 95% CI 1.2–107,

TABLE 3

Sero-surveillance for four zoonotic parasites in Indigenous communities in Canada using the same enzyme-linked immunosorbent assays (ELISA) at the National Reference Centre for Parasitology

Reference	Location	Sample size (*N*)	*Toxoplasma gondii*	*Echinococcus granulosus*	*Toxocara canis*	*Trichinella*
			Sero-prevalence (%)			
Cree						
Levesque, 2007[11]	Mistissini, QC	50	10	0	4	0
Himsworth, 2010[12]	Eastern SK	110	NA	11	NA	NA
Campagna, 2011[13]	James Bay, QC	250	5	4	3	1
Sampasa-Kanyinga, 2012[14]	James Bay, QC	267	9	0.7	4	0
Inuit						
Egeland, 2010[15]	Inuvialuit, NT	362	4	0.6	0.6	0.6
Egeland, 2010[16]	Nunatsiavut, NU	310	7	0.3	1	1
Messier, 2007[17]	Nunavik, QC	917	NA	8	4	NA
Dene						
Schurer, 2012[18]	Northwestern SK	201	14	48	13	16
Saulteaux						
Current study	Southeastern SK	113	2	4	4	3

$P = 0.03$); 2) children (4–17 years of age) were more likely to be exposed to *T. canis* than adults (OR: 49, 95% CI: 3.9–624; $P = 0.003$); and 3) individuals with prior dog bite experience (at least one time) were more likely to be exposed to *T. canis* than those who had never been bitten (OR: 13.5, 95% CI: 1.02–179; $P = 0.048$). No children < 11 years of age ($N = 15$) showed evidence of exposure to *T. canis.*

Survey results including potential routes for parasite transmission and food preparation habits are described in Table 2. Community members owned more dogs than cats ($P < 0.001$), consumed more wild caught meat than wild caught fish ($P < 0.001$), and prepared meat by cooking rather than by drying, smoking, or consuming raw ($P < 0.001$). Many believed that dogs caused problems in the community, with overpopulation, aggression, scavenging garbage bins, running loose, and disease transmission given as the main reasons. Approximately 60% of pet owners did not use veterinary care regularly (many dogs had received puppy vaccination/de-worming by the breeder/seller only), and reasons included cost, distance to a clinic (the nearest clinic is 20 km away), and lack of perceived need. Feeding raw meat to dogs, allowing them to roam freely in the community, and lack of deworming were common practices.

Forty-nine pet owners, three of whom resided outside the communities, brought their animals to the remote clinic in November 2012. Additional dogs were treated at their homes by a mobile team, and several strays were brought in for treatment by community members. The mean age of owned dogs ($N = 64$) brought to the remote clinic was 2.3 years, with 34 males, 26 females, and 4 for whom sex was not determined (1.3:1 male to female ratio). Of owned dogs, 33% were known to have visited a veterinarian in their lifetime, 50% had received only their first set of vaccines, and 6% were known to have been surgically sterilized. Thirty-four percent of dogs had been dewormed (in several cases by our team going door to door in Nov 2011), and 28% owners reported observing ectoparasites on their dogs (14% ticks). There were also 19 cats brought to the clinic (ratio of 3 dogs: 1 cat).

Canine serology and fecal analysis. Overall, 21% (16 of 78) of dogs were sero-positive to *T. gondii*; sero-positivity was significantly higher ($P = 0.042$) in November 2012 than in November 2011 (28%, 13 of 46 and 9%, 3 of 32, respectively). For *B. burgdorferi*, 3% (2 of 77) of dogs were sero-positive overall, with 4% (2 of 46) of dogs sero-positive in 2012, and no sero-positives in 2011. *Cryptosporidium*, *Giardia*, *Alaria*, *T. canis*, *Toxascaris leonina*, *Uncinaria stenocephala*, and *Sarcocystis* species were detected in canine fecal samples (Table 4). The proportion of samples positive for at least one parasite was 62% (16 of 26) in June 2013 and 20% (5 of 25) in November 2011. Parasite richness (number of species) and median egg counts were higher in June 2013 than November 2011.

DISCUSSION

This joint animal and human (One Health) study offers valuable information on dietary preferences, risks, and routes of parasite exposure, issues relating to dog ownership, and use of veterinary services in two Saulteaux Ojibway communities in western Canada (Tables 2 and 3). The overall sero-prevalence of four parasitic zoonoses was low (12%) in relation to previous studies conducted with Dene and Inuit communities in northern Canada. Sero-prevalence for *T. canis*, *T. gondii*, *Echinococcus*, and *Trichinella* were similar to levels observed in Cree communities in north-central Canada, likely reflecting similar preferences for cooked meat.[13,14] However, the exposure to *Echinococcus* in the Saulteaux population in the current study (4% of 113) was lower than in a nearby Cree community (11% of 110) where a clinical case was detected; although it should be noted that the latter study considered equivocal serological results as positive.[12] As compared with the general North America population, sero-prevalence of *T. canis* and *T. gondii* in our study population was low. However, detection of exposure to *Echinococcus* and *Trichinella* would be considered unusual in the general North American population, suggesting that there is some level of exposure to these potentially serious pathogens in the study communities. Antibodies to *Trichinella* are thought to persist for 9–18 months, whereas those for *E. canadensis* and *T. canis* could be lifelong.[17]

We observed a variety of potentially zoonotic parasites in dog feces collected from the environment in the community, including *T. canis*, *Cryptosporidium*, and *Giardia.* Although the number of fecal samples obtained in 2011 and 2013 was low, the combined prevalence (21 of 51; 41%) is comparable to endoparasite levels in canine fecal samples collected from the ground in other Indigenous communities in Saskatchewan.[18] The difference in prevalence between sampling years is likely caused by seasonal and annual variation in climate and diet, with dogs shedding higher numbers of parasites in spring/summer than in fall/winter. Overall, the level of parasitism observed in canine samples from the study community was 10 times higher than levels observed in owned dogs in urban Saskatchewan,[19] which likely reflects the relatively young age of the dogs in the population (~2 years was the mean age of dogs brought

TABLE 4
Prevalence of eggs and cysts of endoparasites in canine fecal samples collected from the ground in November 2011 ($N = 25$) and June 2012 ($N = 26$)

	Prevalence (%)		Intensity mean, median, minimum–maximum (eggs per gram)	
Collection year	2011	2013	2011	2013
Toxocara canis	8	15	6, 6, 5–8	22, 22, 3–43
Toxascaris leonina	4	27	4670, NA, NA	36, 18, 8–65
Uncinaria stenocephala	0	8	0	28, 28, 5–50
Alaria	0	8	0	4, 4, 3–5
Sarcocystis	0	8	0	845, 845, 130–1,560
Giardia	4	12	233, NA, NA	229, 250, 63–375
Cryptosporidium	4	8	133, NA, NA	906, 906, 875–938
Overall*	20	62		

*Overall prevalence was calculated as the number of samples with at least one parasite type divided by the total sample number.

to the remote clinic), and the fact that most dogs in the two communities live outdoors, either exclusively or intermittently, and many are permitted to roam freely. Access to raw meat, lack of deworming, and scavenging of wildlife, and discarded offal, are likely routes of parasite infection.

We detected evidence of exposure to *B. burgdorferi*, the causative agent of Lyme disease, in the dog population of these communities. The sensitivity (99%, 95% CL: 94.3–99.9%) and specificity (99.9%, 95% CL: 97.4–99.9%) of this test are both high, suggesting a high level of confidence in our results.[20] This tick-borne pathogen can cause serious illness in infected people, and public health officials should be aware of its presence in southeastern Saskatchewan. Approximately 14% of dog owners in the study communities reported finding ticks on their dogs in the past year. Although these were most likely adult ticks of *Dermacentor variabilis*, *D. andersoni*, or *Ixodes kingi*, this suggests that these dogs are at high risk of exposure to ticks, including adults and nymphs of *Ixodes scapularis*, the host for *B. burgdorferi*. Therefore, this may reflect a westward expansion of the tick *Ixodes scapularis* from the currently limited endemic region in southern Manitoba in western Canada, or adventitious ticks that have traveled from more southern areas with migratory birds. These serological findings precede diagnosis of human cases in this region of SK, further supporting the idea that dogs are highly suitable as sentinels for this emerging disease, given their higher level of exposure to ticks than people.

We report a relatively low human sero-prevalence for *T. canis* (4%) on par with several other northern studies (Table 3), but lower than the national American average (14%) reported by the Third National Health and Nutrition Examination Survey.[21] This low human sero-prevalence may reflect the fact that many dogs defecated in surrounding bush areas, and thus were less likely to contaminate human environments through parasite eggs in their feces. As well, extremely cold winter conditions may also decrease the human risk of exposure to some infective parasite eggs from dog feces. For example, eggs of *T. canis* have reduced survival when frozen at temperatures of −20 to −30°C, which are normal winter temperatures in this region.[22] This supports an observed latitudinal gradient in prevalence of *T. canis* in dogs and wild canids, with prevalence decreasing as one moves north and the parasite being relatively unknown at latitudes greater than 60°N in Canada.[7] Our regression analysis did not identify dog ownership or feeding raw meat to dogs as significant risk factors for *T. canis* exposure. This finding is similar to two other Canadian studies,[14,23] and suggests that contact with infective eggs in the environment may be the primary exposure route for people, especially in communities where stray dogs are abundant. This study is consistent with previous findings that youth (ages 11–17) are more likely to be exposed to *T. canis* than adults or younger children, highlighting the importance of deworming, and keeping dogs out of areas frequented by youth, such as schoolyards and sandboxes.[24,25] Because this age group is more likely to develop ocular, rather than visceral, larval migrans, follow-up should include retinal examination.[26] Our finding of dog bite history as a risk factor for *T. canis* exposure has not previously been reported. *Toxocara canis* is not transmitted through dog bites, suggesting that our finding is more reflective of frequent exposure to environments contaminated by dog feces.

The sero-prevalence of *Echinococcus* in these communities was similar to that observed in northern Quebec, but lower than levels reported in east-central and north-western Saskatchewan.[12,25] Although we did not find *E. canadensis* in dog feces, infected definitive and intermediate host species are present in the area.[27] Our analysis identified dog ownership to be protective against exposure to this parasite; however, the wide confidence interval suggests that this finding be interpreted with caution. One possibility is that dog owners have higher awareness of the risks associated with contamination of the environment with dog feces, or higher awareness of the need for hand hygiene. Results from this study did not identify gender, age, or hunting/trapping as important risk factors for *E. canadensis* exposure as reported previously,[6,17,25] which could be caused by the low sample size. However, our findings are similar to a related project conducted in a nearby SK community.[12]

We observed evidence of human exposure to *T. gondii* at a level lower than the American average of ~11% in 1999–2004.[28] This may reflect dietary preferences for cooked meat and a relatively small felid population (the definitive host for *T. gondii*), but the estimate might be limited by sample size. The community exposure prevalence for *T. gondii* was higher in dogs than in people, which supports the premise that dogs are more highly exposed and therefore serve as sensitive sentinels for public health. The survey data for these Saulteaux communities identifies risk factors for *T. gondii* exposure and protective mechanisms. Commonly accepted risk factors for exposure include female gender, drinking contaminated water, contact with infected cat feces, having three or more kittens, and ingestion of raw meat, milk, or shellfish.[29,30] In northern Canada, risk factors include female gender, increasing age, frequency of fishing, berry picking, bird handling, cleaning domestic water reservoirs, and consumption of marine mammals, fish, and birds.[31] In our communities, we observed many cats living outdoors, where hunting and eating intermediate hosts (i.e., rodents, birds) is a likely source of infection. Approximately one-fifth of human participants were involved with hunting/trapping and skinning/butchering activities, with approximately equal representation between males and females. No participants ate raw meat, and although smoked or dried meat could potentially contain infective tissue cysts, food-borne transmission does not appear to be a major risk factor for exposure in these communities.

Trichinellosis has been rare in southern Canada since the domestic swine herd was declared to be *Trichinella*-free. However, feral swine have recently become endemic to southern Saskatchewan, and could possibly act as a source of human infection, although the infection status of these animals is not yet clear.[32] In northern areas, the relative risk of human infection is high, and outbreaks have been linked to the consumption of raw bear or walrus meat.[4,33] Risk factors for hospitalization caused by trichinellosis are male gender and age (≥ 21 years of age).[6] The sero-prevalence for *Trichinella* in the current study (3%) was low, similar to that reported in Inuit and Cree communities (0–1%) elsewhere in Canada, but lower than that reported in a Dene community in northwestern Saskatchewan (16%).[11,13,17,18] In other Dene communities in northern Saskatchewan, outbreaks of trichinellosis associated with consumption of black bear have been reported.[4] Saultaux cultural practices, which include cooking game and avoiding consumption of

bear meat, are likely the primary reason for low *Trichinella* levels in this community.

Our survey of the general population participating in the human sero-surveillance study showed that few people used veterinary services regularly, and that common practices such as deworming, vaccination, and surgical alteration to control reproduction, are not widely accepted. Although there were cultural barriers to using vet services, cost and distance were also frequently stated as barriers to using veterinary services, and about 5% of the total population of the two communities brought pets to the remote, low-cost clinic that was based in the community. Interestingly, clinical history data taken from pet owners at a remote veterinary clinic in November 2012 indicated even lower rates of deworming (34%), vaccination (31%), and surgical desexing (6%) in the 64 owned dogs brought to the clinic, although the ratio of dogs to cats brought to the clinic (3:1) was similar to that reported in the survey (2.4:1). In addition, the gender ratio of dogs brought to the clinic (1.3 male: 1 female) confirms anecdotal discussions with community members that male dogs are preferred to female dogs, because of the nuisance of female dogs in heat and the burden of raising puppies. Despite this, follow-up discussions with the community indicated that they did not wish to pursue surgical methods of dog population control at this time.

In contrast with more northern Indigenous populations,[34] the overall risk of human exposure to zoonotic parasites appears to be low in these study communities located in southeastern SK. Although it is difficult to make direct comparisons, we interpreted our results in the context of similar studies using identical laboratory methods in other Canadian Indigenous communities. Community-level differences in parasite exposure and risk factors reflect the presence of important regional, cultural, and dietary differences, and highlights the importance of targeted surveillance and intervention programs tailored specifically for different cultural groups and communities. Finally, we suggest that a One Health approach must go beyond sero-surveillance studies to ensure that surveillance is linked to actions, such as providing reduced cost, culturally acceptable veterinary services to underserved regions, ensuring that study participants have access to follow-up diagnostic testing and treatments, and that researchers need to work with community liaisons (or "brokers") to ensure translation of the results to community members and leaders.

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