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Toxoplasma gondii seroprevalence in veterinarians in Finland: Older age, living in the countryside, tasting beef during cooking and not doing small animal practice associated with seropositivity

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Abstract

Practising veterinary medicine has an inherent risk of exposure to zoonotic agents, including the protozoan parasite *Toxoplasma gondii*. We screened sera of veterinarians authorized to work in Finland for the presence of specific immunoglobulin G antibodies against *T. gondii* with an enzyme-linked fluorescent assay, and evaluated potential risk factors for *T. gondii* seropositivity from extensive questionnaire data with almost 1,300 quantitative variables. We used a causal diagram approach to address the complexity of the life cycle of the parasite and its numerous possible transmission routes, and built a multivariable binomial logistic regression model to identify risk factors that are particularly relevant for veterinarians. The samples and questionnaire data were collected in 2009. Altogether, 294 veterinarians, almost 15% of the Finnish veterinary profession, were included in the study. The median age was 39 years, and the majority, 86%, were women. Altogether, 43 (14.6%; 95% confidence interval: 10.9–19.0) of the 294 veterinarians tested seropositive for *T. gondii*. According to the final model, veterinarians who were at least 40 years old had 2.4 times higher odds to be seropositive than younger veterinarians; veterinarians who lived in the countryside had 4.0 times higher odds to be seropositive than veterinarians who lived in towns; female veterinarians who tasted beef during cooking had 2.6 times higher odds to be seropositive than male veterinarians who did not taste beef during cooking; and veterinarians who did not do small animal practice had 2.3 times higher odds to be seropositive than those who did. The results illustrate the numerous transmission routes of *T. gondii*.

KEYWORDS
occupational health, raw meat, risk factor, small animal practice, toxoplasmosis, zoonotic infection

1 | INTRODUCTION

Practising veterinary medicine has an inherent risk of exposure to numerous zoonotic agents. *Toxoplasma gondii* is a protozoan parasite that belongs to the list of occupational health risks of veterinarians (Weese, Peregrine, & Armstrong, 2002). The infection may cause only mild symptoms and run a subclinical, chronic course, but the parasite can also cause ophthalmologic manifestations and severe, even life-threatening disease, and it is infamous for the damage it can cause to unborn children (Montoya & Liesenfeld, 2004). The risk of vertical transmission is of particular importance for the veterinary profession in countries, such as Finland, where the profession is nowadays predominated by females (Finnish Veterinary Association, 2009; Gold & Beran, 1983; Hirvelä-Koski, Oksanen, & Hämäläinen, 1992; Lindbohm & Taskinen, 2000; Reijula, Bergbom, Lindbohm, & Taskinen, 2005; Reijula et al., 2003).

Toxoplasma gondii infection or exposure to the parasite has been documented in numerous animal species in Finland, including pet animals such as domestic cats (Jokelainen, Simola, et al., 2012; Must, Hytönen, Orro, Lohi, & Jokelainen, 2017); domestic animals such as sheep (Jokelainen et al., 2010) and pigs (Felin, Jukola, Raulo, & Fredriksson-Ahomaa, 2015); semidomesticated reindeer (*Rangifer tarandus tarandus*) (Oksanen, Åsbakk, Nieminen, Norberg, & Näreaho, 1997) and farmed wild boars (*Sus scrofa*) (Jokelainen, Näreaho, Hälli, Heinonen, & Sukura, 2012); and free-ranging wildlife such as moose (*Alces alces*), roe deer (*Capreolus capreolus*) and white-tailed deer (*Odocoileus virginianus*) (Jokelainen et al., 2010), European brown hares (*Lepus europaeus*) and mountain hares (*Lepus timidus*) (Jokelainen, Isomursu, Näreaho, & Oksanen, 2011), Eurasian lynxes (*Lynx lynx*) (Jokelainen et al., 2013), and Eurasian red squirrels (*Sciurus vulgaris*) (Jokelainen & Nylund, 2012). Moreover, *T. gondii* is recognized as one of the main occupational hazards for veterinarians in Finland (Reijula et al., 2005). However, literature searches identified no epidemiological studies on *T. gondii* focusing on veterinarians in Finland nor in the other Nordic countries.

Toxoplasma gondii infection can be detected serologically. The aims of our seroepidemiological study were to estimate *T. gondii* seroprevalence among veterinarians in Finland and to evaluate risk factors for *T. gondii* seropositivity, with emphasis on plausible occupational risk factors. We used a causal diagram approach to address the numerous possible transmission routes and built a multivariable binomial logistic regression model to identify risk factors that are particularly relevant for veterinarians.

Impacts

- *Toxoplasma gondii* seroprevalence was 14.6% in veterinarians in Finland.
- A causal diagram approach was applied to identify risk factors for *T. gondii* infection, from almost 1,300 quantitative variables.
- Older age, living in the countryside, tasting beef during cooking and not doing small animal practice were identified as risk factors for T. gondii seropositivity in veterinarians in Finland.

2 | MATERIALS AND METHODS

2.1 | Ethics statement

The study was approved by the Ethic Committee of Helsinki University Central Hospital (number 303/13/03/00/2009). Participation was voluntary, and the participants gave a written informed consent. The sera and data were coded, and serology and statistical analyses were performed blinded. The serology results were communicated to participants who wished to receive their results.

2.2 | Setting and study design

Finland is a Nordic country, located in northern Europe. In 2009, there were about 2,000 veterinarians in Finland, and more than half of them attended the national Annual Veterinary Congress (Finnish Veterinary Association, 2009).

Our study was a cross-sectional seroepidemiological study. Sampling was convenience sampling, the sampling frame comprised veterinarians attending the national Annual Veterinary Congress in 2009, and the target population was veterinarians authorized to work in Finland.

2.3 | Samples

Blood samples were collected at the Annual Veterinary Congress, which was held in Helsinki from 28 October to 30 October 2009, for a larger scale study on zoonotic infections of veterinarians in Finland, as described earlier (Kantala et al., 2017). For this study, we included the sera from participants from whom we had both a serum sample and a completed questionnaire, and who reported being authorized to work as a veterinarian in Finland (n = 295).

2.4 | Questionnaire

An extensive electronic questionnaire was used to collect information about possible exposures to several zoonotic pathogens in and outside the veterinary work. The skip-pattern questionnaire was available in Finnish and Swedish, the main official languages of Finland.

Questions covering age, gender and health were asked first, followed by questions about work, work environment, use of personal protective equipment and animal contacts at work. The animal species and animal groups specifically asked about were camelids, cats, cattle, dogs, fish, fur animals, that is animals farmed for their fur, goats, horses, pet birds, pet rodents, pigs, poultry, rabbits, reindeer, reptiles, sheep, wild boars and wildlife. Further questions covered,

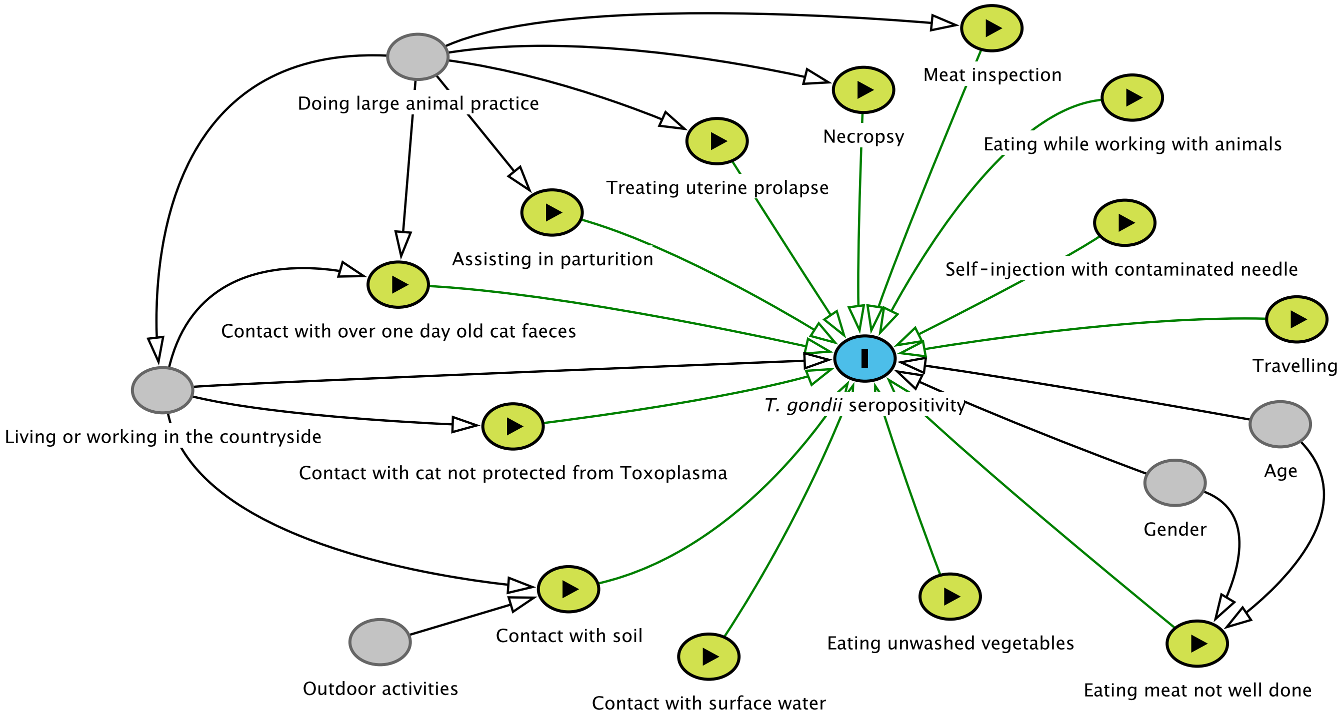

FIGURE 1 Causal diagram for plausible risk factors for *Toxoplasma gondii* seropositivity in veterinarians in Finland [Colour figure can be viewed at wileyonlinelibrary.com]

for example living environment, free-time outdoor activities, travelling, having pets at home, dietary habits and kitchen hygiene.

2.5 | Serology

The sera were screened for *T. gondii*-specific immunoglobulin G (IgG) antibodies with an enzyme-linked fluorescent assay (VIDAS TOXO IgG II; bioMérieux S.A., Marcy l'Etoile, France). Results >8 IU/ml were considered positive, and results <4 IU/ml were considered negative. Samples with equivocal result were re-tested once and classified according to the result of the second run. Samples repeatedly yielding an equivocal result were excluded from the statistical analyses.

2.6 | Statistical analyses

The data were handled in Microsoft Excel, and the statistical analyses were performed using SPSS (version 22.0.0.0, IBM, New York, USA). The questionnaire data were analysed considering both biological and statistical aspects (Siponen, 2016).

The outcome was dichotomous: each veterinarian was either *T. gondii*-seronegative or *T. gondii*-seropositive. Out of almost 1,300 quantitative variables, we first selected the biologically plausible exposure variables based on a causal diagram (Figure 1, Textor, Hardt, & Knüppel, 2011). Further selection was done based on statistical significance. The exposure variables were dichotomized (no exposure vs. exposure).

The 95% confidence intervals (CIs) were calculated using Jeffrey's method (Brown, Cai, & DasGupta, 2001) with EpiTools (Sergeant, 2017). The Bonferroni method was used to reduce type 1 error. Cross-tabulations (chi-square or Fisher's exact test) were first separately performed for each variable. Variables with *p*-value >0.2, variables with >50% missing data and variables with $n < 20$ in one of the categories were excluded. Crude logistic regression analyses with only one independent variable in the model at a time were run to all the variables with *p*-value <0.2 from cross-tabulation. Variables with Wald's *p*-value >0.2 were excluded at this point. Moreover, if two variables had a Spearman correlation coefficient >0.8, the one considered biologically less relevant or having fewer observations was excluded. Finally, the excluded variables were considered for re-inclusion based on the causal diagram, and variables "gender" as well as "doing small animal practice," "doing production animal practice" and "doing equine practice" were re-included. After these steps, 20 variables remained (Table 1).

Multivariable logistic regression model was built by offering all the 20 variables into the model followed by manual stepwise exclusion of those with highest Wald *p*-value until only statistically significant variables were left. The variables were checked for interaction, in particular with gender as suggested by the causal diagram, as well as for the presence of confounding. We present odds ratios (ORs). The final model was evaluated using, for example, Nagelkerke's R^2, Hosmer–Lemeshow test and area under the receiver operating characteristic (ROC) curve.

3 | RESULTS

Both serum sample and questionnaire data were available from 295 veterinarians. One veterinarian was excluded from further analyses

TABLE 1 Prevalence of anti-*Toxoplasma gondii* immunoglobulin G antibodies in veterinarians (n = 294) in Finland

Variables[a]	n	Seroprevalence (%)	95% confidence interval	Wald's p-value
Age (years)				
<40	148	9.5	5.5–15.0	0.013*
≥40	146	19.9	14.0–26.9	
Veterinary authorization				
In the 2000s	139	10.1	5.9–15.9	0.063
Before year 2000	152	17.8	12.3–24.4	
Gender				
Male	40	20.0	9.9–34.2	0.304
Female	254	13.8	10.0–18.4	
History of zoonotic disease				
No	226	12.8	9.0–17.7	0.188
Yes	44	20.5	10.6–34.0	
Small animal practice				
Yes	207	13.0	9.0–18.1	0.329
No	86	17.4	10.6–23.2	
Production animal practice				
No	153	12.4	7.9–18.3	0.329
Yes	140	16.4	11.0–23.2	
Equine practice				
No	195	12.8	8.7–18.0	0.299
Yes	98	17.3	10.9–25.7	
Contact to pet birds at work				
No	160	16.9	11.7–23.2	0.176
Yes	133	11.3	6.7–17.5	
Contact to reptiles at work				
No	168	17.3	12.1–23.5	0.101
Yes	125	10.4	6.6–16.6	
Investigation of bovine diarrhoea samples				
No	158	11.4	7.1–17.0	0.093
Yes	136	18.4	12.6–25.5	
Caesarean sections of sheep/goats/camelids				
No	209	11.5	7.7–16.3	0.019*
Yes	93	22.4	14.5–32.0	
Meat inspection of sheep/goats/camelids				
No	214	12.1	8.3–17.0	0.052
Yes	80	21.3	13.4–31.1	
Veterinary procedures to cats or dogs				
No	46	21.7	11.8–35.1	0.141
Yes	248	13.3	9.5–18.0	
Living in the countryside				
No	210	10.5	6.9–15.2	0.003*
Yes	81	24.7	16.3–34.9	
Owning cat(s) and presence of wild rodents in the dwelling house				
No	229	12.7	8.8–17.4	0.048
Yes (both)	61	23.0	13.8–34.6	

(Continues)

TABLE 1 (Continued)

Variables[a]	*n*	Seroprevalence (%)	95% confidence interval	Wald's *p*-value
Owning cat(s) with access outdoors				
No	203	12.3	8.3–17.4	0.069
Yes	87	20.7	13.2–30.1	
Mushroom picking during previous 5 years				
No	61	8.2	3.2–17.0	0.172
Yes	215	15.8	11.4–21.1	
Eating raw beef				
No	217	11.5	7.8–16.3	0.013*
Yes	77	23.4	15.0–33.7	
Tasting beef during cooking				
No	208	8.7	5.4–13.0	0.000**
Yes	86	29.1	20.3–39.2	
Tasting lamb/mutton during cooking				
No	271	13.3	9.6–17.7	0.031*
Yes	23	30.4	14.8–50.7	
Total	294	14.6	10.9–19.0	

[a]Data on some variables were missing for some veterinarians. The variables are shown so that the option that was coded as "0" for the models is mentioned first. *Statistically significant difference, $p < 0.05$. **Statistically significant difference, $p < 0.0025$ (Bonferroni corrected)

TABLE 2 The variables of the final multivariable logistic regression model for *Toxoplasma gondii* seropositivity in veterinarians in Finland

Variable[a]	Odds ratio	95% confidence interval	*p*-value (Wald)
Age ≥40 years	2.446	1.107–5.405	0.027
Living in the countryside	4.003	1.855–8.640	0.000
Female gender	0.370	0.099–1.384	0.140
Tasting beef during cooking	0.732	0.125–4.305	0.730
Female gender × tasting beef during cooking	9.658	1.333–70.007	0.025
No small animal practice	2.274	1.041–4.969	0.039

[a]The variables were dichotomous; each was compared with the opposite.

due to repeatedly equivocal serology result. Therefore, the final sample size for the statistical analyses was 294 veterinarians.

The median age among the 294 veterinarians included in this study was 39 years (range: 23–79 years). The majority, 86% ($n = 254$), were women. The median age was 38 years in women and 51 years in men.

Anti-*T. gondii* IgG antibodies were detected in 43 of the 294 veterinarians, yielding an apparent seroprevalence estimate of 14.6% (95% CI: 10.9–19.0; Table 1).

Based on cross-tabulations, seven of the 20 variables appeared statistically associated ($p < 0.05$) with *T. gondii* seropositivity (Table 1). The most striking observation was that the proportion testing seropositive for *T. gondii* was more than three times higher among those veterinarians who reportedly tasted beef during cooking than among those who did not (29.1% and 8.7%, respectively, $p < 0.0025$, Bonferroni correction 0.05/20; Table 1).

The final multivariable binomial logistic regression model for *T. gondii* seropositivity, estimated using data of 290 of the veterinarians, from which we had data for all the variables, is shown in Table 2. The model had one interaction term, and the variable "not doing small animal practice" acted as a confounder. In the model, $\text{logit}(Y) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + e$; where e represents the residual value, the constant b_0 was −2.885; $b_1 = 0.895$, X_1 = age; $b_2 = 1.387$, X_2 = living in the countryside; $b_3 = -0.994$, X_3 = gender; $b_4 = -0.312$, X_4 = tasting beef during cooking; $b_5 = 2.268$, $X_5 = X_3X_4$ = gender × tasting beef during cooking; and $b_6 = 0.822$, X_6 = not doing small animal practice; thus, the model was $\text{logit}(Y) = -2.885 + 0.895\ X_1 + 1.387\ X_2 - 0.994\ X_3 - 0.312\ X_4 + 2.268\ X_3X_4 + 0.822\ X_6$.

The model was statistically significant ($\chi^2(6) = 40.269$, $p = 0.000$); it explained 23.3% of variance and classified 86.9% of the 290 veterinarians (244 of the 249 seronegatives and eight of the 41 seropositives) correctly. The Hosmer–Lemeshow *p*-value was 0.823. The area under the ROC curve was 0.779 (95% CI: 0.701–0.858), indicating moderate predictive ability (Greiner, Pfeiffer, & Smith, 2000). The sensitivity of the model was low, 19.5%, while specificity was

98.0%. Positive predictive value was 61.5%, and negative predictive value was 88.1%. There were 14 outliers (studentized residuals >2.0) who were erroneously predicted as seronegative. Ten of them had mentioned eating raw red meat at least sometimes—a variable that was not included in the model—while three reported eating meat only well done and one was vegetarian. Excluding any of these would not have changed the model substantially, except the OR of the interaction term "female gender × tasting beef during cooking" (range: excluding an observation would have increased the OR of the interaction term with 2.7, whereas excluding another would have decreased it with 2.5).

According to the model, veterinarians who were at least 40 years old had 2.4 times higher odds to be seropositive than the younger veterinarians; veterinarians who lived in the countryside had 4.0 times higher odds to be seropositive than veterinarians who lived in towns; female veterinarians who tasted beef during cooking had 2.6 times higher odds to be seropositive than male veterinarians who did not taste beef during cooking; and veterinarians who did not do small animal practice had 2.3 times higher odds to be seropositive than those who did. The second last odds ratio (female veterinarians who tasted beef during cooking vs. male veterinarians who did not taste beef during cooking) is the ratio between $odds_1$ and $odds_2 = e^{logit(Y1)}/e^{logit(Y2)} = e^{-1,923}/e^{-2,885} = 2.6$, where $logit(Y_1) = \ln(odds_1) = -2.885 + 0.895*0 + 1.387*0 - 0.994*1 - 0.312*1 + 2.268*1*1 + 0.822*0 = -1.923$, and $logit(Y_2) = \ln(odds_2) = -2.885 + 0.895*0 + 1.387*0 - 0.994*0 - 0.312*0 + 2.268*0*0 + 0.822*0 = -2.885$.

For example, the probability to be seropositive was 5% for a male veterinarian who was younger than 40 years of age, lived in a town, did not report tasting beef during cooking and did do small animal practice ($e^{-2.885}/(1 + e^{-2.885}) = 0.0529$; $logit(Y) = -2.885 + 0.895*0 + 1.387*0 - 0.994*0 - 0.312*0 + 2.268*0*0 + 0.822*0 = -2.885$), whereas the probability to be seropositive was 77% for a female veterinarian who was over 40 years old, lived in the countryside, reported tasting beef during cooking and did not do small animal practice ($e^{1.181}/(1 + e^{1.181}) = 0.7651$; $logit(Y) = -2.885 + 0.895*1 + 1.387*1 - 0.994*1 - 0.312*1 + 2.268*1*1 + 0.822*1 = 1.181$).

4 | DISCUSSION

The proportion of veterinarians participating in this study who tested seropositive for *T. gondii* (14.6%, 95% CI: 10.9–19.0) was lower than the seroprevalence estimate of 20.3% (n = 16,733, 95% CI: 19.6–21.1) among pregnant women in 1988–1989 in the region of Helsinki, the capital of Finland (Lappalainen et al., 1992). The estimate of the seroprevalence for 2000–2001 from a nationally representative sample of individuals aged 30 years or over, 19.7% (95% CI: 18.3–21.1) (Suvisaari, Torniainen-Holm, Lindgren, Härkänen, & Yolken, 2017), was closer to our estimate for veterinarians in 2009. These observations may reflect a general decrease in seroprevalence over time, which has been observed in several countries, such as the Netherlands (Hofhuis et al., 2011), France (Nogareda, Strat, Villena, Valk, & Goulet, 2014) and the United States (Jones, Kruszon-Moran, Rivera, Price, & Wilkins, 2014)—however not in all, such as Estonia (Lassen et al., 2016). The seroprevalence among veterinarians was thus of the expected order of magnitude when compared with the other estimates published from Finland (Lappalainen et al., 1992; Suvisaari et al., 2017). The results of different studies are, however, not directly comparable due to different study designs and methodologies applied.

In comparison with the global focus on *T. gondii* as a zoonotic foodborne pathogen of major public health concern (FAO/WHO, 2014), there has been relatively little epidemiological research of this parasite as an occupational risk (Alvarado-Esquivel, Estrada-Martínez, & Liesenfeld, 2011; Alvarado-Esquivel, Liesenfeld, Estrada-Martínez, & Félix-Huerta, 2011; Alvarado-Esquivel et al., 2008, 2014; Alvarado-Esquivel, Liesenfeld, Márquez-Conde, Estrada-Martínez, & Dubey, 2010; Holec-Gasior, Stańczak, Myjak, & Kur, 2008; Ibrahim, Salama, Gawish, & Haridy, 1997; Kolbekova, Kourbatova, Novotna, Kodym, & Flegr, 2007; Lassen et al., 2016; Lings, Lander, & Lebech, 1994; Seuri & Koskela, 1992; Sroka, Zwoliński, & Dutkiewicz, 2003). In particular, the geographical coverage of published studies including analyses of risk factors for veterinarians is limited (Alvarado-Esquivel et al., 2014; Brandon-Mong et al., 2015; Nowotny et al., 1997; Sang-Eun et al., 2014; Shuhaiber et al., 2003; Tizard & Caoili, 1976; Zimmermann, 1976). Moreover, the studies are challenging to compare due to different approaches used, variables evaluated and methods applied, and therefore, the reasons for the apparent similarities and differences remain largely unknown. For example, the seroprevalence among veterinary personnel in Canada, 14.2% (n = 141, 95% CI: 8.4–19.9, Shuhaiber et al., 2003), was very similar to our estimate for Finland. By contrast, a more recent seroprevalence estimate for veterinarians in Estonia, a country located near Finland, was 46.2% (n = 158, 95% CI: 38.5–54.0, Lassen et al., 2016), which is 3-fold higher than our estimate for veterinarians in Finland. The age distribution of the veterinarians included in the Estonian study does not offer an explanation for this difference: in a subset of 115 veterinarians that has been described in more detail (Lassen et al., 2017), the median age was 35 years, which is lower than the median age of 39 years in our study. Other reasons can only be speculated; the extent of work-related or non-work-related exposure to the parasite as well as protective measures applied against the parasite could be different between the two countries.

The results of our risk factor analyses illustrated the complexity of the transmission routes of *T. gondii*. Older age was a significant risk factor for seropositivity, indicating that the infections are typically acquired infections, and the other risk factors suggested different, both work-related and non-work-related infection sources. Of the risk factors identified, tasting beef while cooking is an easily avoidable one, and one that should be known to the profession. Tasting meat during cooking and eating raw or undercooked beef were also among the risk factors identified in a multicentre study among pregnant women (Cook et al., 2000). Our observation of doing small animal veterinary practice appearing as a protective factor merits further investigation.

The study population included almost 15% of the target population, Finnish veterinary profession (Finnish Veterinary Association, 2009). Majority of the participating veterinarians were women, which reflects the gender distribution in the profession (Finnish Veterinary Association, 2009). A wide age range and a wide variety of veterinary work were represented. However, the sampling took place at a single professional event and participation was voluntary; thus, the veterinarians who attended professional education events, were interested in research projects or, in particular, were interested in the research project focusing on zoonoses might be overrepresented. Unfortunately, comparing the results to a control group (non-veterinarians) was not possible. We did also sample other participants of the event, but the size of that group was limited and it included, for example, veterinary nurses and veterinary students, who are likely exposed quite similar to veterinarians.

Serology is an indirect method that is widely used in epidemiological *T. gondii* studies. Testing only one antibody class can be regarded as a limitation of our study; however, IgG antibodies are the most suitable for epidemiological studies. The presence of specific IgG antibodies indicates previous exposure to the parasite, but the exact time of acquiring the infection remains unknown, and acute infections are missed. Acute infections where IgG antibodies are not yet produced or measurable were expected to be relatively rare in this population.

Our electronic questionnaire could have introduced some measurement error in our study (Dillman, Smyth, & Christian, 2014). The questionnaire was extensive because it was designed to cover questions that were relevant to several zoonoses, and it was laborsome to complete. Some questions had relatively long instructional texts, and table format used for some multiple-choice questions was too large to fit one monitor view. Moreover, as we included no confirming questions that could have served to validate the answers, some erroneous answers were possible. We believe the veterinarians answered honestly, but recall bias was possible. That so many veterinarians completed the questionnaire can be considered an indication of positive attitude towards research and interest towards the topic.

While *T. gondii* is recognized as occupational health risk for veterinarians, in particular as a risk for unborn children of female veterinarians and as a reasoning for a special maternity allowance (Health Insurance Act, 2004; Hirvelä-Koski et al., 1992; Lindbohm & Taskinen, 2000; Reijula et al., 2005, 2003; The Social Insurance Institution of Finland, 2017), the parasite is handled very differently in the different types of veterinary work. Good personal hygiene is emphasized when treating ill cats (Dubey, 2010). The tissue-dwelling forms of *T. gondii* are handled carefully in biosafety level 2 laboratories by researchers, and veterinary pathologists use personal protective equipment when performing necropsies, but meat inspection does not even attempt to detect *T. gondii*-infected animals at the slaughterhouses. Environmental contamination with *T. gondii* oocysts has been discussed as an occupational health risk at horse stables (Teutsch, Juranek, Sulzer, Dubey, & Sikes, 1979) and zoos (Dubey, 2010), while, for example, cat shelters and small animal hospitals with domestic cats as in-patients have not been emphasized, although such locations could become contaminated with *T. gondii* oocysts. In our study, doing equine practice was not identified as a risk factor, and doing small animal veterinary practice appeared as a protective factor. The latter could perhaps be explained by good general hygiene in small animal clinics.

In summary, our study showed that 14.6% of the veterinarians investigated in Finland had serological evidence of exposure to the zoonotic parasite *T. gondii*. The results of the risk factor analyses illustrated the complexity of the transmission routes, which include possible routes related and unrelated to veterinary work.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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