



ELSEVIER

Contents lists available at ScienceDirect

Veterinary Parasitology

journal homepage: www.elsevier.com/locate/vetpar

The prevalence of *Giardia* infection in dogs and cats, a systematic review and meta-analysis of prevalence studies from stool samples

Maha Bouzid*, Kapil Halai, Danielle Jeffreys, Paul R. Hunter

Norwich Medical School, University of East Anglia, NR4 7TJ Norwich, UK

ARTICLE INFO

Article history:

Received 18 July 2014

Received in revised form

10 December 2014

Accepted 12 December 2014

Keywords:

Giardia

Cats

Dogs

Prevalence

Zoonotic

Meta-analysis

ABSTRACT

Giardia has a wide range of host species and is a common cause of diarrhoeal disease in humans and animals. Companion animals are able to transmit a range of zoonotic diseases to their owners including giardiasis, but the size of this risk is not well known. The aim of this study was to analyse giardiasis prevalence rates in dogs and cats worldwide using a systematic search approach. Meta-analysis enabled to describe associations between *Giardia* prevalence and various confounding factors. Pooled prevalence rates were 15.2% (95% CI 13.8–16.7%) for dogs and 12% (95% CI 9.2–15.3%) for cats. However, there was very high heterogeneity between studies. Meta-regression showed that the diagnostic method used had a major impact on reported prevalence with studies using ELISA, IFA and PCR reporting prevalence rates between 2.6 and 3.7 times greater than studies using microscopy. Conditional negative binomial regression found that symptomatic animals had higher prevalence rates ratios (PRR) than asymptomatic animals 1.61 (95% CI 1.33–1.94) in dogs and 1.94 (95% CI 1.47–2.56) in cats. *Giardia* was much more prevalent in young animals. For cats >6 months, PRR = 0.47 (0.42–0.53) and in dogs of the same age group PRR = 0.36 (0.32–0.41). Additionally, dogs kept as pets were less likely to be positive (PRR = 0.56 (0.41–0.77)) but any difference in cats was not significant. Faecal excretion of *Giardia* is common in dogs and slightly less so in cats. However, the exact rates depend on the diagnostic method used, the age and origin of the animal. What risk such endemic colonisation poses to human health is still unclear as it will depend not only on prevalence rates but also on what assemblages are excreted and how people interact with their pets.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Giardia is a common cause of acute gastroenteritis in humans and many animal species across the globe. *Giardia* is one of the most important protozoan pathogens causing diarrhoeal disease, in both developed and developing countries. In the USA, *Giardia* incidence ranges from 7.4 to

7.6 cases per 100,000 populations (Geurden et al., 2008) and in the United Kingdom, an incidence of 5.5 cases per 100,000 people was reported in 2005 (Feng and Xiao, 2011). However, these figures are almost certainly an underestimate and about 2.8×10^8 new cases are likely to occur in humans per annum (Lane and Lloyd, 2002). Furthermore, chronic giardiasis can lead to malabsorption and failure to thrive in children increasing the disease burden due to this infection (Cotton et al., 2011). Although *Giardia* does cause disease, it can also be asymptomatic in humans and animals (Ballweber et al., 2010). A recent large scale

* Corresponding author. Tel.: +44 1603 597176.
E-mail address: m.bouzid@uea.ac.uk (M. Bouzid).

case–control study in developing countries by Kotloff and colleagues found no association between *Giardia* infection and moderate to severe diarrhoea in infants and young children (Kotloff et al., 2013). Interestingly, the authors reported higher *Giardia* prevalence rates in the control group. This is in accordance with the findings of Veenmans and colleagues who reported that *Giardia* infection can be associated with a protective effect against diarrhoea in developing countries (Veenmans et al., 2011). However, the mechanisms of this protection are not fully understood.

The fact that *Giardia* can infect both human and animals has raised concerns about the risk to public health from companion animals (Thompson et al., 2008). The level of risk depends on prevalence rates and excretion patterns. However, this risk is only linked to the presence of human infective *Giardia* assemblages (A and B) (Caccio et al., 2005). In an excellent review of *Giardia* in cats and dogs, Ballweber and colleagues noted that reported prevalence of *Giardia* in stools varied from one study to another and in part this variation was associated with geography, detection method, age of animal, whether or not symptomatic and where the animal was housed (Ballweber et al., 2010). However, the authors did not formally test these observations and so we are not yet able to fully quantify the impact that such factors have on reported animal prevalence. In order to better define the prevalence of *Giardia* in cats and dogs, we performed a systematic review and meta-analysis. In addition, we undertook a series of regression analyses to further investigate and so quantify the impact certain factors would have on apparent prevalence.

2. Methods

2.1. Search strategy

The Ovid/Medline and CAB abstracts databases were searched for studies that reported on the prevalence of *Giardia* in either dogs or cats. All studies that reported on cats or dogs were included, providing that the authors stated how many samples were tested, how many were positive and the detection method. To remove potential bias for historical studies that may have not used modern detection methods; we restricted our search to papers published from 2001 onward. The initial search using the exploded MESH search terms in Ovid “*Giardia*” and “prevalence” and “cats” or “dogs” was run in September 2011 and updated in October 2014. The more agricultural and veterinary focused database CAB abstracts was searched in October 2014 using the following search terms: “dog or dogs or canine or canines” and “*Giardia*” and “prevalence” for dogs and “cat” or “cats” or “canine or “canines” and “*Giardia*” and “prevalence” for cats. The retrieved papers were screened using title and abstract and all eligible papers were retained for full text analysis.

2.2. Data extraction

For each prevalence study, the following were recorded: (1) host species, (2) location of study, (3) clinical signs, (4) age range and origin (pet or other), (5) method of detection,

(6) total number of faecal samples, and (7) number of *Giardia* positive samples

2.3. Data analysis

Data was initially recorded on Microsoft Excel. For the calculation of pooled prevalence, data was transferred into Stats Direct™ (<http://www.statsdirect.co.uk/>). Random effects pooled prevalence and heterogeneity were calculated and Forest plots generated. Publication bias was assessed by means of funnel plots and Harbord’s bias index. Where a paper presented subgroup analyses, these were combined for the initial meta-analysis except where these subgroups were based on whether or not the animals tested were known to be symptomatic or asymptomatic. Where prevalence results for sub-groups were presented in the original paper (in terms of age group and animal origin), subsequent analyses treated these as separate study arms to assess the effect of these variables on prevalence rates.

The impact of predictors of prevalence was tested using STATA version 13.0. For the two predictors that were known for all studies (region and diagnostic method), random effects negative binomial regression was performed, with region and diagnostic method as confounding variables. For those parameters that were only extractable for a limited number of studies (symptoms, age group and whether or not the animals were pets), we used conditional negative binomial regression. In this regression, only those studies that had reported each subgroup in the same paper were included and so this was effectively a matched analysis (Cummings and McKnight, 2004).

3. Results

The database searches retrieved 594 papers. Title and abstract scanning enabled us to exclude 123 studies (Fig. 1). 374 studies were retained for investigation. During data extraction, further 205 papers were excluded because of one of the following reasons: do not satisfy inclusion criteria including other host species, present the same results as another paper published by the same author (generally same year of publication), inability of access full length article and language of publication. One paper was identified through reference lists and was included. Therefore 169 papers were retained for analysis. Details of all included studies are given in Table 1. Out of these 169 papers, 127 had data on dogs and 68 on cats. Table 2 summarises the characteristics of the included studies according to the detection method and geographical region. All further analyses were done separately on dogs and cats.

3.1. Prevalence in dogs

Amongst the 127 papers in dogs (150 study arms), samples were obtained from 4,309,451 animals, of which 112,513 (2.61%) were positive. Fig. 2 shows the forest plot for all included studies ordered by detection method and reducing prevalence. The random effects

Table 1Characteristic of included studies used for *Giardia* prevalence meta-analysis from dogs and cats.

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Dogs	Egypt	Mixed	3 age groups (pet and police dogs)	Microscopy	180	21	0.12	2012–2013	2014	(Ahmed et al., 2014)
Dogs	Brazil	Symptomatic	No age groups (pets)	PCR	104	14	0.13	Not stated	2014	(Gizzi et al., 2014)
Dogs	Brazil	Asymptomatic	No age groups (pets)	PCR	43	2	0.05	Not stated	2014	(Gizzi et al., 2014)
Dogs	Brazil	Unknown	2 age group (shelter and pet shop)	Microscopy	80	34	0.43	2011–2012	2014	(Mota et al., 2014)
Dogs	Portugal	Symptomatic	4 age groups (pets)	Microscopy	193	30	0.16	2008–2010	2014	(Neves et al., 2014)
Dogs	Portugal	Asymptomatic	4 age groups (pets)	Microscopy	175	13	0.07	2008–2010	2014	(Neves et al., 2014)
Dogs	Spain	Unknown	No age group (shelter and hunting)	Microscopy	169	64	0.38	Not stated	2014	(Ortuno et al., 2014)
Dogs	Italy	Symptomatic	6 age groups (pets and kennels)	Microscopy	435	124	0.29	2007–2010	2014	(Pipia et al., 2014)
Dogs	Italy	Asymptomatic	6 age groups (pets and kennels)	Microscopy	220	48	0.22	2007–2010	2014	(Pipia et al., 2014)
Dogs	Canada	Unknown	2 age groups (pets)	ELISA	251	16	0.06	2009	2014	(Procter et al., 2014)
Dogs	Cambodia	Unknown	No age group (pets)	PCR	94	2	0.02	2012	2014	(Schar et al., 2014)
Dogs	Canada	Unknown	2 age group (pets)	IFA	251	62	0.25	2010	2014	(Smith et al., 2014)
Dogs	Taiwan	Unknown	No age groups (strays)	PCR	118	11	0.09	2010–2011	2014	(Tseng et al., 2014)
Dogs	Iran	Unknown	2 age groups (strays)	Microscopy	100	9	0.09	2013	2014	(Yagoob and Bahman, 2014)
Dogs	Iran	Asymptomatic	2 age group (pets)	Microscopy	210	2	0.01	2010	2014	(Gharekhani, 2014)
Dogs	USA	Mixed	No age group (shelter)	IFA	672	196	0.29	2006–2009	2014	(Johansen et al., 2014)
Dogs	China	Unknown		ELISA	318	51	0.16	Not stated	2014	(Yang et al., 2014)
Dogs	Italy	Mixed	2 age groups (pets)	ELISA	208	42	0.20	2010–2011	2014	(Zanzani et al., 2014)
Dogs	Venezuela	Unknown	3 age group (pets)	Microscopy	98	14	0.14	2007	2013	(Cazorla Perfetti and Morales Moreno, 2013)
Dogs	Brazil	Unknown	No age groups (pets)	Microscopy	195	33	0.17	2009–2012	2013	(Farias et al., 2013)
Dogs	China	Unknown	2 age group (farm and police)	PCR	205	27	0.13	2011	2013	(Li et al., 2013)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Dogs	Trinidad and Tobago	Unknown	2 age groups (kennel and stray)	Microscopy	104	26	0.25	2010–2011	2013	(Mark-Carew et al., 2013)
Dogs	USA	Mixed	4 age groups (pets)	Microscopy	2,468,359	10,843	0.00	2003–2009	2013	(Mohamed et al., 2013)
Dogs	Brazil	Asymptomatic	6 age groups (strays)	Microscopy	357	19	0.05	2011–2012	2013	(Quadros et al., 2013)
Dogs	Italy	Mixed	No age group (pets)	Microscopy	239	9	0.04	2008–2010	2013	(Riggio et al., 2013)
Dogs	India	Symptomatic	3 age group (pets)	ELISA	120	49	0.41	2010–2011	2013	(Shikha et al., 2013)
Dogs	Peru	Symptomatic	4 age groups (pets)	Microscopy	180	21	0.12	2009–2010	2013	(Sotelo et al., 2013)
Dogs	Peru	Asymptomatic	4 age groups (pets)	Microscopy	120	29	0.24	2009–2010	2013	(Sotelo et al., 2013)
Dogs	Canada	Unknown	1 age group (mixed)	IFA	209	61	0.29	2006	2013	(Uehlinger et al., 2013)
Dogs	Brazil	Mixed	No age group (mixed origin)	Microscopy	300	48	0.16	2007–2009	2012	(Paz e Silva et al., 2012)
Dogs	Ivory Coast	Unknown	No age group (free roaming domestic animals)	PCR	11	6	0.55	Not stated	2012	(Berrilli et al., 2012)
Dogs	Romania	Unknown	2 age groups (mixed origin)	ELISA	416	144	0.35	2008–2009	2012	(Mircean et al., 2012)
Dogs	USA	Unknown	No age category (pets)	Microscopy	129	5	0.04	2009–2010	2012	(Wang et al., 2012)
Dogs	Germany	Unknown	2 age groups (stray)	ELISA	341	39	0.11	2006–2007	2012	(Becker et al., 2012)
Dogs	Spain	Unknown	No age group (shelter)	Microscopy	604	99	0.16	Not stated	2012	(Dado et al., 2012)
Dogs	China	Symptomatic	3 age group (pets)	PCR	57	15	0.26	2010–2011	2012	(Li et al., 2012)
Dogs	China	Asymptomatic	3 age group (pets)	PCR	152	8	0.05	2010–2011	2012	(Li et al., 2012)
Dogs	Peru	Unknown	4 age groups (pets)	Microscopy	130	19	0.15	2008	2012	(Pablo et al., 2012)
Dogs	Canada	Unknown	No age group (pets)	IFA	231	48	0.21	2009–2011	2012	(Schurer et al., 2012)
Dogs	Poland	Asymptomatic	>12 months Sled dogs	IFA	108	31	0.29	2009–2010	2011	(Bajer et al., 2011)
Dogs	USA	Asymptomatic	No age category (pets)	Microscopy	519,585	35,172	0.07	2009	2011	(Covacin et al., 2011)
Dogs	Japan	Asymptomatic	≤3 months (pet shop puppies)	ELISA	1794	420	0.23	2007–2009	2011	(Itoh et al., 2011a)
Dogs	Japan	Symptomatic	2 age groups (pets)	ELISA	128	19	0.15	2008–2010	2011	(Itoh et al., 2011b)

Dogs	Japan	Asymptomatic	2 age groups (pets)	ELISA	2237	177	0.08	2008–2010	2011	(Itoh et al., 2011b)
Dogs	Germany	Mixed	6 age categories (pets)	ELISA	24,677	4591	0.19	2003–2011	2011	(Barutzki and Schaper, 2011)
Dogs	Costa Rica	Mixed	No age group (pets)	IFA	58	5	0.09	2009	2011	(Scorza et al., 2011)
Dogs	Canada	Unknown	No age category (pets)	IFA	75	10	0.13	2007	2011	(Bryan et al., 2011)
Dogs	Portugal	Unknown	No age category (household and kennels)	Microscopy	126	31	0.25	2007–2008	2011	(Ferreira et al., 2011)
Dogs	Canada	Unknown	3 age groups (household and shelter)	Microscopy	619	50	0.08	2008–2009	2011	(Joffe et al., 2011)
Dogs	Romania	Unknown	4 age group (pets)	Microscopy	1500	45	0.03	2008–2010	2011	(Amfim et al., 2011)
Dogs	Spain	Unknown	No age group (shelter)	Microscopy	544	221	0.41	2005–2008	2011	(Ortuño and Castellà, 2011)
Dogs	European countries	Symptomatic	4 age categories (pets)	ELISA	6683	1827	0.27	2005–2006	2010	(Epe et al., 2010)
Dogs	European countries	Asymptomatic	4 age categories (pets)	ELISA	1915	305	0.16	2005–2006	2010	(Epe et al., 2010)
Dogs	European countries	Unknown	4 age categories (pets)	ELISA	87	20	0.23	2005–2006	2010	(Epe et al., 2010)
Dogs	Galapagos Islands	Asymptomatic	No age groups (pets)	IFA	97	5	0.05	Not stated	2010	(Gingrich et al., 2010)
Dogs	USA	Mixed	No age group (racing dogs)	IFA	120	10	0.08	2008	2010	(McKenzie et al., 2010)
Dogs	Japan	Mixed	Exact age given (pets)	Microscopy	77	2	0.03	2006–2010	2010	(Yoshiuchi et al., 2010)
Dogs	Canada	Symptomatic	5 age group but no prevalence info (vet clinic)	ELISA	1871	241	0.13	2006	2010	(Olson et al., 2010)
Dogs	Canada	Unknown	No age group (unknown origin as environmental samples)	Microscopy	155	95	0.61	Not stated	2010	(Himsworth et al., 2010)
Dogs	Brazil	Unknown	No age group (strays)	Microscopy	46	1	0.02	2005	2010	(Klimpel et al., 2010)
Dogs	South Africa	Unknown	No age group (strays)	Microscopy	240	13	0.05	2008–2009	2010	(Mukaratirwa and Singh, 2010)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Dogs	Poland	Unknown	No age group (shelter or privately owned)	Microscopy	148	3	0.02	Not stated	2010	(Solarczyk and Majewska, 2010)
Dogs	Argentina	Unknown	No age group (unknown origin)	Microscopy	1944	25	0.01	2005–2008	2010	(Soriano et al., 2010)
Dogs	London	Unknown	2 age groups (strays)	ELISA	878	87	0.10	2006–2007	2010	(Upjohn et al., 2010)
Dogs	Mexico	Unknown	6 age group (shelter)	Microscopy	147	10	0.07	2006–2007	2010	(Jiménez-Cardoso et al., 2010)
Dogs	Iran	Unknown	2 age groups (stray)	Microscopy	98	7	0.07	2009	2010	(Mirzaei, 2010)
Dogs	Iran	Symptomatic	3 age groups (pets)	ELISA	27	5	0.19	2007–2010	2010	(Mosallanejad et al., 2010b)
Dogs	Iran	Asymptomatic	3 age groups (pets)	ELISA	123	1	0.01	2007–2010	2010	(Mosallanejad et al., 2010b)
Dogs	Belgium	Symptomatic	No age group (diagnostic lab)	IFA	351	64	0.18	2004–2007	2009	(Claerebout et al., 2009)
Dogs	Belgium	Asymptomatic	No age group (dog schools, owners, kennels)	IFA	808	199	0.25	2004–2007	2009	(Claerebout et al., 2009)
Dogs	Netherlands	Asymptomatic	No age group (household dogs)	ELISA	92	16	0.17	2007	2009	(Overgaauw et al., 2009)
Dogs	Italy	Symptomatic	2 age groups (kennels)	PCR	22	13	0.59	2005–2006	2009	(Scaramozzino et al., 2009)
Dogs	Italy	Asymptomatic	2 age groups (kennels)	PCR	105	13	0.12	2005–2006	2009	(Scaramozzino et al., 2009)
Dogs	USA	Unknown	No age group (vet clinic)	Microscopy	6555	216	0.03	1997–2007	2009	(Gates and Nolan, 2009)
Dogs	Japan	Unknown	No age group (household dogs)	Microscopy	1105	137	0.12	1997, 2002, 2007	2009	(Itoh et al., 2009)
Dogs	USA	Unknown	5 age groups (vet clinic)	Microscopy	1,199,293	48,353	0.04	Not stated	2009	(Little et al., 2009)
Dogs	Romania	Symptomatic	2 age groups (pets)	Microscopy	153	24	0.16	2006–2007	2009	(Coman et al., 2009)
Dogs	Spain	Unknown	No age group (shelter and pets)	Microscopy	505	31	0.06	1999–2000	2009	(Gracenea et al., 2009)
Dogs	Italy	Unknown	No age groups (pets)	PCR	143	44	0.31	2008	2009	(Papini et al., 2009)
Dogs	Brazil	Unknown	No age group (pets)	Microscopy	81	9	0.11	2006–2007	2009	(Prates et al., 2009)
Dogs	Iran	Unknown	No age group (pet and farm)	Microscopy	174	1	0.01	2006–2007	2009	(Razmi, 2009)

Dogs	Thailand	Unknown	No age group (semi-domesticated in temples)	PCR	104	73	0.70	2004	2009	(Traub et al., 2009)
Dogs	Belgium	Symptomatic	No age group (pets)	IFA	141	42	0.30	Not stated	2008	(Geurden et al., 2008)
Dogs	Belgium	Asymptomatic	No age group (pets)	IFA	272	34	0.13	Not stated	2008	(Geurden et al., 2008)
Dogs	South Korea	Symptomatic	3 age categories (kennels)	ELISA	42	20	0.48	2008	2008	(Liu et al., 2008)
Dogs	South Korea	Asymptomatic	3 age categories (pets)	ELISA	430	33	0.08	2008	2008	(Liu et al., 2008)
Dogs	Serbia	Asymptomatic	One age group (>1 year) pets, strays and military dogs	Microscopy	151	22	0.15	Not stated	2008	(Nikolic et al., 2008)
Dogs	UK	Symptomatic	7 age groups in a graph (household dogs)	Microscopy	4526	380	0.08	2003–2005	2008	(Batchelor et al., 2008)
Dogs	Brazil	Unknown	2 age groups (strays and pets)	Microscopy	254	39	0.15	2004–2005	2008	(Katagiri and Oliveira-Sequeira, 2008)
Dogs	Brazil	Unknown	3 age categories (housed and shelter)	Microscopy	200	33	0.17	Not stated	2008	(Meiros et al., 2008)
Dogs	Australia	Unknown	No age group (refuge and vet clinic)	Microscopy	1400	130	0.09	2004–2005	2008	(Palmer et al., 2008)
Dogs	Italy	Unknown	No age category (faecal samples)	ELISA	415	32	0.08	2005	2008	(Rinaldi et al., 2008)
Dogs	Brazil	Symptomatic	4 age group (pets)	ELISA	228	23	0.10	2006–2007	2008	(Labarthe et al., 2008)
Dogs	Brazil	Asymptomatic	4 age group (pets)	ELISA	1609	156	0.10	2006–2007	2008	(Labarthe et al., 2008)
Dogs	Argentina	Unknown	2 age group (shelter and pets)	Microscopy	46	5	0.11	2004	2008	(Lavallén et al., 2011)
Dogs	UK	Symptomatic	No age group (to be hearing dogs)	Microscopy	59	6	0.10	Not stated	2007	(Guest et al., 2007)
Dogs	UK	Asymptomatic	No age group (to be hearing dogs)	Microscopy	549	46	0.08	Not stated	2007	(Guest et al., 2007)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Dogs	Finland	Asymptomatic	2 age groups (pets)	IFA	150	8	0.05	2003–2004	2007	(Rimhanen-Finne et al., 2007)
Dogs	Spain	Mixed	4 age groups (housed and homeless)	Microscopy	251	1	0.00	Not stated	2007	(Martinez-Carrasco et al., 2007)
Dogs	Czech Republic	Unknown	No age category (faecal samples from city and rural)	Microscopy	4320	49	0.01	1998–2001	2007	(Dubna et al., 2007)
Dogs	Norway	Unknown	4 age categories (pets)	IFA	290	60	0.21	1999–2002	2007	(Hamnes et al., 2007)
Dogs	Thailand	Unknown	No age group (pets)	Microscopy	229	18	0.08	Not stated	2007	(Inpankaew et al., 2007)
Dogs	Spain	Unknown	4 age groups (housed and homeless)	Microscopy	1800	18	0.01	Not stated	2007	(Martinez-Moreno et al., 2007)
Dogs	Spain	Unknown	No age group (strays)	Microscopy	1161	82	0.07	Not stated	2007	(Miro et al., 2007)
Dogs	Brazil	Unknown	2 age groups (strays)	Microscopy	410	119	0.29	Not stated	2007	(Mundim et al., 2007)
Dogs	Greece	Unknown	2 age groups (shepherd and hunting)	Microscopy	281	12	0.04	2003–2004	2007	(Papazahariadou et al., 2007)
Dogs	Brazil	Unknown	5 age group (pets)	Microscopy	1473	392	0.27	2002–2004	2007	(Lorenzini et al., 2007)
Dogs	Brazil	Unknown	2 age groups (pets)	Microscopy	53	16	0.30	2006	2007	(Pinto et al., 2007)
Dogs	Brazil	Symptomatic	4 age groups (pets)	Microscopy	150	14	0.09	2004–2005	2007	(Santos et al., 2007)
Dogs	Brazil	Asymptomatic	4 age groups (pets)	Microscopy	50	3	0.06	2004–2005	2007	(Santos et al., 2007)
Dogs	Slovakia	Unknown	3 age groups (mixed origin)	Microscopy	752	12	0.02	2006	2007	(Szabová et al., 2007)
Dogs	Hungary	Unknown	9 age groups (pets and kennels)	ELISA	187	110	0.59	2004–2006	2007	(Szénási et al., 2007)
Dogs	Brazil	Unknown	No age group (pets)	PCR	10	7	0.70	2003–2005	2007	(Volotão et al., 2007)
Dogs	USA	Symptomatic	No age category (pets)	ELISA	16,064	2506	0.16	Not stated	2006	(Carlin et al., 2006)
Dogs	Italy	Symptomatic	4 age groups (pets, kennels and strays)	Microscopy	91	22	0.24	2001–2003	2006	(Capelli et al., 2006)
Dogs	Italy	Asymptomatic	4 age groups (pets, kennels and strays)	Microscopy	158	20	0.13	2001–2003	2006	(Capelli et al., 2006)

Dogs	Canada	Asymptomatic	No age group (pets visiting hospitals)	ELISA	102	7	0.07	2004	2006	(Lefebvre et al., 2006)
Dogs	Chile	Symptomatic	2 age groups (pets)	Microscopy	972	211	0.22	1996–2003	2006	(Lopez et al., 2006)
Dogs	Argentina	Unknown	4 age groups (pets)	Microscopy	2193	195	0.09	2003–2004	2006	(Fontanarrosa et al., 2006)
Dogs	Canada	Unknown	2 age categories (pets)	Microscopy	70	5	0.07	2004	2006	(Shukla et al., 2006)
Dogs	Costa Rica	Unknown	No age group (pets)	Microscopy	1136	227	0.20	2002–2004	2006	(Arguedas Zeledón et al., 2006)
Dogs	Brazil	Unknown	No age group (pet)	Microscopy	95	8	0.08	2001	2006	(Labruna et al., 2006)
Dogs	Poland	Asymptomatic	No age group (city and rural dogs)	ELISA	86	46	0.53	Not stated	2005	(Gundlach et al., 2005)
Dogs	Brazil	Asymptomatic	2 age groups and 2 dog origins	Microscopy	166	52	0.31	Not stated	2005	(Huber et al., 2005)
Dogs	Japan	Symptomatic	2 age groups (kennels)	ELISA	64	24	0.38	2003–2004	2005	(Itoh et al., 2005)
Dogs	Japan	Asymptomatic	2 age groups (kennels)	ELISA	297	111	0.37	2003–2004	2005	(Itoh et al., 2005)
Dogs	USA	Symptomatic	No age group (shelter)	IFA	49	18	0.37	2002	2005	(Sokolow et al., 2005)
Dogs	USA	Asymptomatic	No age group (shelter)	IFA	49	18	0.37	2002	2005	(Sokolow et al., 2005)
Dogs	Italy	Mixed	2 age groups (shelter)	ELISA	183	101	0.55	2004	2005	(Papini et al., 2005)
Dogs	Mexico	Unknown	No age group (strays)	Microscopy	200	93	0.47	1997–1998	2005	(Ponce-Macotela et al., 2005)
Dogs	Brazil	Unknown	No age group (pets and stray)	Microscopy	434	6	0.01	2001–2002	2005	(Alves et al., 2005)
Dogs	Germany	Asymptomatic	No age group (shelter)	ELISA	264	78	0.30	Not stated	2004	(Cirak and Bauer, 2004)
Dogs	Japan	Unknown	No age group (pets)	Microscopy	772	22	0.03	1979, 1991, 2001	2004	(Asano et al., 2004)
Dogs	Canada	Asymptomatic	No age group (research facility)	Microscopy	107	11	0.10	2002	2004	(Anderson et al., 2004)
dogs	Italy	Symptomatic	2 age groups (pets and strays)	ELISA	8	3	0.38	2003	2004	(Bianciardi et al., 2004)
Dogs	Italy	Asymptomatic	2 age groups (pets and strays)	ELISA	97	17	0.18	2003	2004	(Bianciardi et al., 2004)
Dogs	USA	Symptomatic	No age group (pets)	IFA	71	4	0.06	1997–1998	2003	(Hackett and Lappin, 2003)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Dogs	USA	Asymptomatic	No age group (pets)	IFA	59	3	0.05	1997–1998	2003	(Hackett and Lappin, 2003)
Dogs	Germany	Unknown	No age group (pets)	ELISA	8438	1400	0.17	1999–2002	2003	(Barutzki and Schaper, 2003)
Dogs	India	Unknown	No age group (dogs in close contact with humans)	PCR	101	20	0.20	Not stated	2003	(Traub et al., 2003)
Dogs	Brazil	Mixed	2 age group (kennel)	Microscopy	100	41	0.41	Not stated	2003	(Mundim et al., 2003)
Dogs	Brazil	Asymptomatic	2 age groups (pets and strays)	Microscopy	271	33	0.12	1999–2000	2002	(Oliveira-Sequeira et al., 2002)
Dogs	Serbia	Asymptomatic	No age groups (pets, stray, farm)	Microscopy	167	24	0.14	Not stated	2002	(Nikolić et al., 2002)
Dogs	Brazil	Unknown	No age group (pets)	Microscopy	250	49	0.20	2002–2001	2002	(Rufino et al., 2002)
Dogs	Japan	Symptomatic	4 age groups (pets)	Microscopy	407	88	0.22	Not stated	2001	(Itoh et al., 2001)
Dogs	Japan	Asymptomatic	4 age groups (pets)	Microscopy	628	63	0.10	Not stated	2001	(Itoh et al., 2001)
Dogs	japan	Symptomatic	No age group (presumably pets as sampled from animal hospitals)	ELISA	71	35	0.49	2000	2001	(Mochizuki et al., 2001)
Dogs	Japan	Asymptomatic	No age group (presumably pets as sampled from animal hospitals)	ELISA	10	4	0.40	2000	2001	(Mochizuki et al., 2001)
Dogs	Canada	Mixed	4 age groups (pets)	ELISA	1216	93	0.08	1999	2001	(Jacobs et al., 2001)
Dogs	Brazil	Asymptomatic	No age group (stray)	Microscopy	140	4	0.03	Not stated	2001	(Carollo et al., 2001)
Cats	Iran	Unknown	No age group (stray)	Microscopy	140	15	0.11	2012	2014	(Khademvatan et al., 2014)
Cats	Albania	Unknown	No age group (pet)	ELISA	58	17	0.29	2008–2011	2014	(Knaus et al., 2014)
Cats	UK	Symptomatic	3 age groups (pets)	PCR	1088	225	0.21	2010–2012	2014	(Paris et al., 2014)
Cats	USA	Symptomatic	No age group (cat sanctuary)	PCR	68	38	0.56	2009–2012	2014	(Polak et al., 2014)
Cats	Italy	Asymptomatic	No age group (pets)	PCR	146	11	0.08	Not stated	2014	(Mancianti et al., 2014)

Cats	Italy	Mixed	2 age groups (pets)	ELISA	127	35	0.28	2010–2011	2014	(Zanzani et al., 2014)
Cats	Hungary	Unknown	No age group (pets)	ELISA	115	43	0.37	2011	2013	(Capari et al., 2013)
Cats	Brazil	Unknown	5 age groups (pets)	Microscopy	191	8	0.04	2011	2013	(Pivoto et al., 2013)
Cats	Italy	Mixed	No age group (pets)	Microscopy	81	1	0.01	2008–2010	2013	(Riggio et al., 2013)
Cats	Italy	Unknown	No age groups (strays)	ELISA	139	4	0.03	Not stated	2013	(Spada et al., 2013)
Cats	Canada	Mixed	4 age group (pets)	IFA	283	28	0.10	1998–2008	2013	(Hoopes et al., 2013)
Cats	USA	Symptomatic	No age group (pets and shelter)	ELISA	219	18	0.08	2007–2009	2012	(Queen et al., 2012)
Cats	USA	Asymptomatic	No age group (pets and shelter)	ELISA	54	1	0.02	2007–2009	2012	(Queen et al., 2012)
Cats	Finland	Unknown	No age group (pets)	ELISA	402	13	0.03	2009–2010	2012	(Nareaho et al., 2012)
Cats	Germany	Unknown	2 age groups (stray)	ELISA	584	40	0.07	2006–2007	2012	(Becker et al., 2012)
Cats	Spain	Unknown	No age group (shelter)	Microscopy	144	6	0.04	Not stated	2012	(Dado et al., 2012)
Cats	Romania	Symptomatic	3 age categories (pets)	ELISA	50	16	0.32	2007–2009	2011	(Mircean et al., 2011)
Cats	Romania	Asymptomatic	3 age categories (pets)	ELISA	67	11	0.16	2007–2009	2011	(Mircean et al., 2011)
Cats	Japan	Asymptomatic	3 age categories (cat cafes)	Microscopy	321	26	0.08	2003–2010	2011	(Suzuki et al., 2011)
Cats	Germany	Mixed	6 age categories (pets)	ELISA	8560	1082	0.13	2003–2010	2011	(Barutzki and Schaper, 2011)
Cats	Costa Rica	Mixed	No age group (pets)	IFA	7	4	0.57	2009	2011	(Scorza et al., 2011)
Cats	Portugal	Unknown	No age category (household and kennels)	Microscopy	22	3	0.14	2007–2008	2011	(Ferreira et al., 2011)
Cats	Poland	Unknown	No age category (vet clinic)	Microscopy	160	6	0.04	2006–2007	2011	(Jaros et al., 2011)
Cats	Canada	Unknown	3 age groups (household and shelter)	Microscopy	153	0	0.00	2008–2009	2011	(Joffe et al., 2011)
Cats	Egypt	Unknown	No age groups (strays)	Microscopy	113	2	0.02	2010	2011	(Khalafalla, 2011)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Cats	Italy	Unknown	Exact age given (pets and strays)	PCR	181	11	0.06	2006–2009	2011	(Paoletti et al., 2011)
Cats	Norway	Mixed	2 age groups (show cats)	IFA	52	4	0.08	2009	2011	(Tysnes et al., 2011)
Cats	European countries	Symptomatic	4 age categories (pets)	ELISA	3331	765	0.23	2005–2006	2010	(Epe et al., 2010)
Cats	European countries	Asymptomatic	4 age categories (pets)	ELISA	871	89	0.10	2005–2006	2010	(Epe et al., 2010)
Cats	European countries	Unknown	4 age categories (pets)	ELISA	12	2	0.17	2005–2006	2010	(Epe et al., 2010)
Cats	New Zealand	Mixed	No age group (show cats)	ELISA	22	7	0.32	2006	2010	(Kingsbury et al., 2010)
Cats	Japan	Mixed	Exact age given (pets)	Microscopy	55	1	0.02	2006–2010	2010	(Yoshiuchi et al., 2010)
Cats	Canada	Symptomatic	6 age group but no prevalence info (vet clinic)	ELISA	389	16	0.04	2006	2010	(Olson et al., 2010)
Cats	USA	Unknown	No age groups (shelter and foster homes)	Microscopy	1629	145	0.09	2006–2010	2010	(Lucio-Forster and Bowman, 2011)
Cats	Romania	Unknown	2 age groups (pets)	Microscopy	414	3	0.01	2007–2009	2010	(Mircean et al., 2010)
Cats	Brazil	Mixed	No age groups (pets)	Microscopy	166	58	0.35	Not stated	2010	(Dall'Agnol et al., 2010)
Cats	Iran	Symptomatic	3 age groups (pets)	ELISA	23	4	0.17	2008–2010	2010	(Mosallanejad et al., 2010a,b)
Cats	Iran	Asymptomatic	3 age groups (pets)	ELISA	127	1	0.01	2008–2010	2010	(Mosallanejad et al., 2010a,b)
Cats	UK	Asymptomatic	No age category (pets)	ELISA	55	3	0.05	2006–2007	2009	(Gow et al., 2009)
Cats	Netherlands	Asymptomatic	No age group (household cats)	ELISA	22	3	0.14	2007	2009	(Overgaauw et al., 2009)
Cats	Australia	Mixed	No age group (cattery and shelter)	ELISA	149	15	0.10	2006–2007	2009	(Bissett et al., 2009)
Cats	Brazil	Unknown	No age group (cats for euthanasia)	Microscopy	51	3	0.06	2007	2009	(Coelho et al., 2009)
Cats	USA	Unknown	No age group (vet clinic)	Microscopy	1566	36	0.02	1997–2007	2009	(Gates and Nolan, 2009)
Cats	Iran	Unknown	No age group (strays)	Microscopy	113	1	0.01	2004–2005	2009	(Mohsen and Hosseini, 2009)
Cats	Iran	Unknown	No age group (stray)	Microscopy	113	1	0.01	2004–2005	2009	(Arbabi and Hooshyar, 2009)

Cats	USA	Mixed	No age group (pets)	IFA	250	34	0.14	Not stated	2009	(Ballweber et al., 2009)
Cats	Romania	Symptomatic	2 age groups (pets)	Microscopy	23	6	0.26	2006–2007	2009	(Coman et al., 2009)
Cats	Spain	Unknown	No age group (shelter)	Microscopy	50	2	0.04	1999–2000	2009	(Gracenea et al., 2009)
Cats	UK	Symptomatic	2 age groups (pets)	Microscopy	1403	76	0.05	2003–2007	2008	(Tzannes et al., 2008)
Cats	Iran	Unknown	No age group (pets)	Microscopy	147	1	0.01	Not stated	2008	(Jafari Shoorijeh et al., 2008)
Cats	Australia	Unknown	No age group (refuge and vet clinic)	Microscopy	1063	22	0.02	2004–2005	2008	(Palmer et al., 2008)
Cats	Brazil	Symptomatic	4 age group (pets)	ELISA	124	22	0.18	2006–2007	2008	(Labarthe et al., 2008)
Cats	Brazil	Asymptomatic	4 age group (pets)	ELISA	338	50	0.15	2006–2007	2008	(Labarthe et al., 2008)
Cats	USA	Symptomatic	No age group (shelters)	IFA	177	24	0.14	Not stated	2007	(Mekaru et al., 2007)
Cats	USA	Asymptomatic	No age group (shelters)	IFA	177	10	0.06	Not stated	2007	(Mekaru et al., 2007)
Cats	Italy	Symptomatic	3 age groups (strays and pets)	ELISA	24	6	0.25	2004	2007	(Papini et al., 2007)
Cats	Italy	Asymptomatic	3 age groups (strays and pets)	ELISA	242	36	0.15	2004	2007	(Papini et al., 2007)
Cats	USA	Mixed	5 age groups (pets)	IFA	250	34	0.14	Not stated	2007	(Vasilopoulos et al., 2007)
Cats	Brazil	Unknown	5 age group (pets)	Microscopy	288	59	0.20	2002–2004	2007	(Lorenzini et al., 2007)
Cats	Italy	Unknown	4 age group (stray)	Microscopy	76	2	0.03	2005–2006	2007	(Natale et al., 2007)
Cats	Brazil	Unknown	No age group (pets)	PCR	1	1	1.00	2003–2005	2007	(Volotão et al., 2007)
Cats	Japan	Symptomatic	4 age groups (pets)	ELISA	132	57	0.43	2003–2005	2006	(Itoh et al., 2006)
Cats	Japan	Asymptomatic	4 age groups (pets)	ELISA	468	183	0.39	2003–2005	2006	(Itoh et al., 2006)
Cats	USA	Mixed	5 age groups (pets)	Microscopy	211,105	1223	0.01	2003–2004	2006	(De Santis-Kerr et al., 2006)
Cats	USA	Symptomatic	No age category (pets)	ELISA	4977	538	0.11	Not stated	2006	(Carlin et al., 2006)
Cats	Chile	Symptomatic	2 age groups (pets)	Microscopy	230	44	0.19	1996–2003	2006	(Lopez et al., 2006)

Table 1 (Continued)

Host species	Location	Clinical signs	Age groups and origin	Detection method	Total	Positives	Prevalence rate	Collection period	Publication year	Reference
Cats	Colombia	Unknown	3 age groups (strays or unwanted)	PCR	46	3	0.07	2005	2006	(Santin et al., 2006)
Cats	Canada	Unknown	2 age categories (pets)	Microscopy	41	1	0.02	2004	2006	(Shukla et al., 2006)
Cats	Germany	Asymptomatic	No age group (shelter)	ELISA	98	22	0.22	Not stated	2004	(Cirak and Bauer, 2004)
Cats	USA	Mixed	No age group (show cats from catteries)	ELISA	117	36	0.31	2001	2004	(Gookin et al., 2004)
Cats	Italy	Symptomatic	2 age groups (pets and strays)	ELISA	6	0	0.00	2003	2004	(Bianciardi et al., 2004)
Cats	Italy	Asymptomatic	2 age groups (pets and strays)	ELISA	42	2	0.05	2003	2004	(Bianciardi et al., 2004)
Cats	Germany	Unknown	No age group (pets)	ELISA	3167	399	0.13	1999–2002	2003	(Barutzki and Schaper, 2003)
Cats	Australia	Unknown	No age group (not pets)	PCR	40	32	0.80	Not stated	2003	(McGlade et al., 2003)
Cats	Brazil	Unknown	No age group (stray)	Microscopy	66	8	0.12	Not stated	2003	(Serra et al., 2003)
Cats	USA	Mixed	No age group (shelter)	Microscopy	50	16	0.32	Not stated	2002	(Zajac et al., 2002)
Cats	Serbia	Asymptomatic	2 age groups (pets)	Microscopy	81	18	0.22	Not stated	2002	(Nikolić et al., 2002)
Cats	USA	Mixed	<1 year old cats (pets and shelter)	Microscopy	263	19	0.07	1998–1999	2001	(Spain et al., 2001)

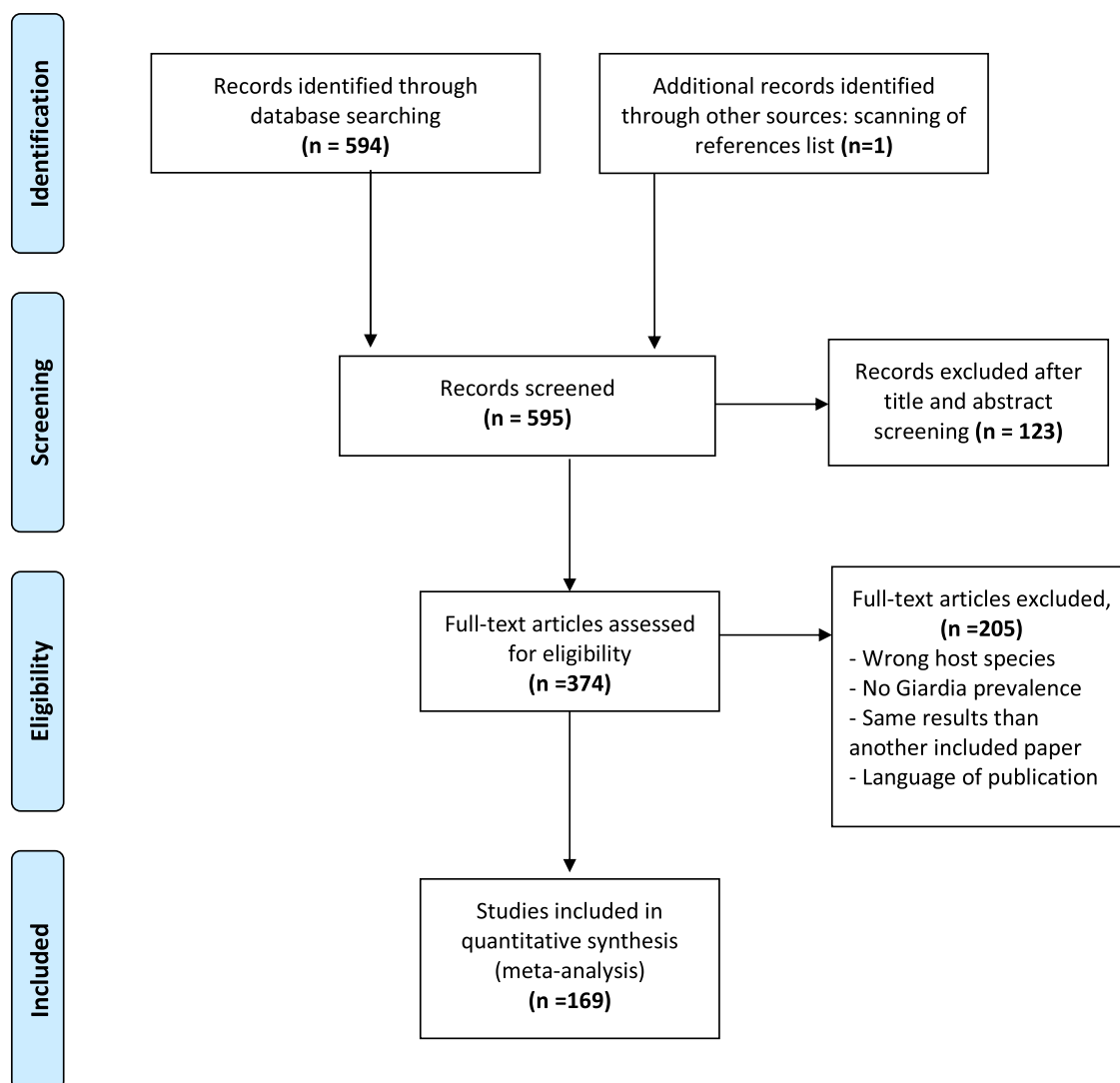


Fig. 1. Flow diagram describing paper selection and inclusion/exclusion process according to PRISMA guidelines.

Table 2
Region and diagnostic method for included studies.

Characteristic	Dogs		Cats	
	N = 127	%	N = 68	%
Region				
Africa	3	2.4	1	1.5
Asia	23	18.1	8	11.8
Australasia	1	0.8	4	5.9
Europe	43	33.9	29	42.6
North America	22	17.3	16	23.5
South America	35	27.6	10	14.7
Diagnostic method				
ELISA	28	22.0	24	35.3
IFA	15	11.8	6	8.8
Microscopy	73	57.5	31	45.6
PCR	11	8.7	7	10.3

pooled prevalence of all studies for canines was 15.2% (95% CI 13.8–16.7%). Heterogeneity was, however, very high $I^2 = 99.9\%$. As can be seen in the funnel plot (supplementary file 1A), there is a strong suggestion of publication bias towards publication of high prevalence studies (Harbord: bias = 20.9 (92.5% CI = 15.1–26.7) $P < 0.0001$).

3.2. Prevalence in cats

Amongst the 68 papers (78 study arms) on cats, 248,195 samples were tested of which 5,807 (2.33%) were positive. The forest plot for the cat studies is shown in Fig. 3. The random effects pooled prevalence is 12% (95% CI 9.2–15.3%). Once again there was very high heterogeneity $I^2 = 99.3\%$. As with the data from dogs, there is a strong suggestion of publication bias towards publication of high prevalence studies (Harbord: bias = 15.6 (92.5% CI = 10.8–20.3) $P < 0.0001$) (supplementary file 1B).

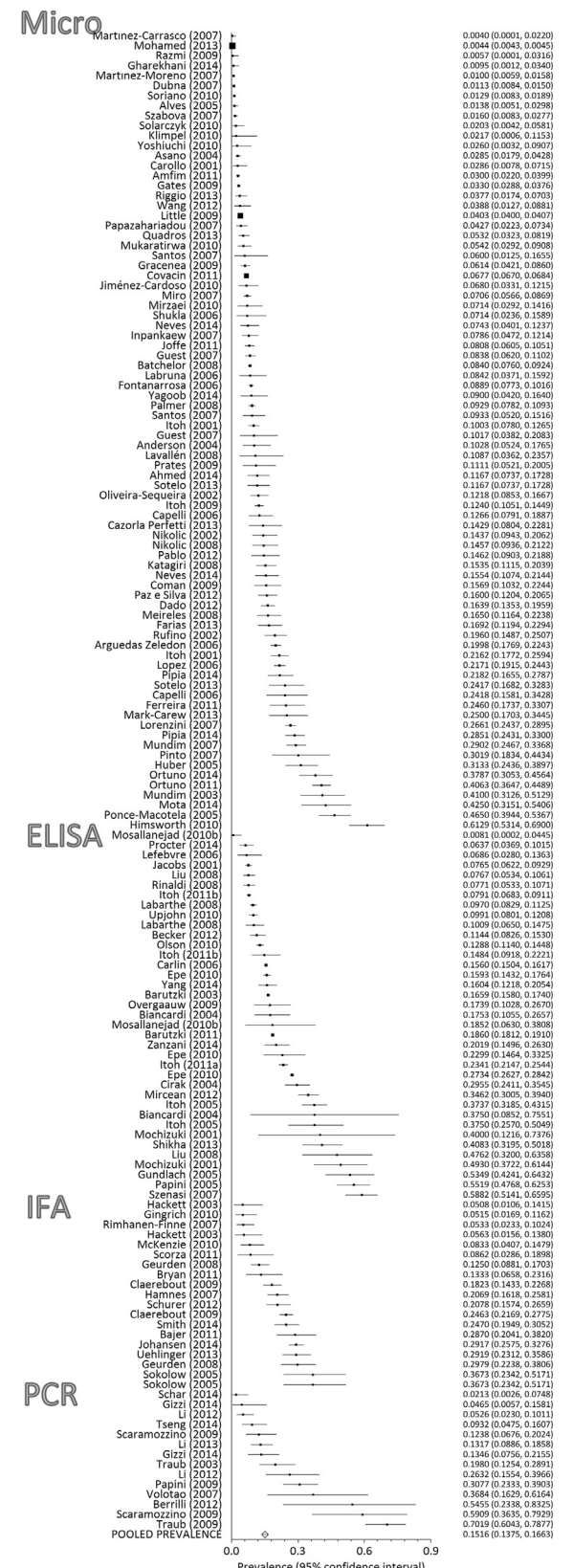


Fig. 2. Forest plot for prevalence studies in dogs ordered by detection method and reducing prevalence.

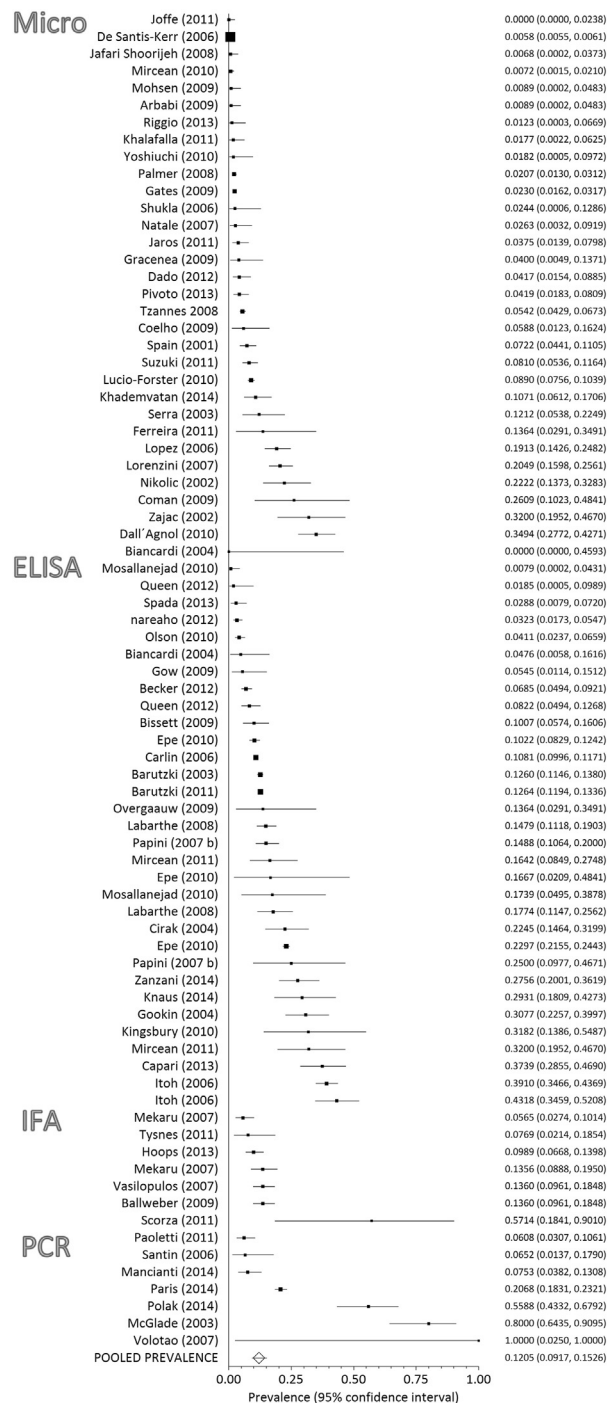


Fig. 3. Forest plot for prevalence studies in cats ordered by detection method and reducing prevalence.

3.3. Predictors of prevalence in cats and dogs

Table 3 gives the estimates of the impact of key study characteristics on *Giardia* prevalence in dogs and cats. Region and diagnostic method were tested together in a single random effects model. Given that data on the other predictors (origin of animal (Kennel/stray or pet),

Table 3
Predictors of *Giardia* prevalence rates in dogs and cats using panel negative binomial regression.

Characteristic	Dogs					Cats				
	No. groups conditional regression	Prevalence rate ratio	Lower 95% CI	Upper 95% CI	P	No. groups conditional regression	Prevalence rate ratio	Lower 95% CI	Upper 95% CI	P
Region ^a										
Europe		1			0.046		1			0.022
Africa		1.68	0.56	5.02			0.71	0.09	5.42	
Asia		0.77	0.48	1.24			0.87	0.40	1.89	
Australasia		1.46	0.29	7.28			1.37	0.52	3.61	
North America		0.82	0.51	1.32			0.78	0.42	1.47	
South America		1.61	1.06	2.45			2.73	1.40	5.30	
Diagnostic method ^b										
Microscopy		1			<0.0001		1			0.0001
ELISA		2.26	1.49	3.42			2.68	1.60	4.48	
IFA		2.48	1.47	4.19			3.75	1.65	8.48	
PCR		2.42	1.32	4.45			3.51	1.58	7.78	
Clinical signs ^c										
Asymptomatic	22	1			<0.0001	9	1			<0.0001
Symptomatic		1.61	1.33	1.94			1.94	1.47	2.56	
Origin of animals ^d										
Strays/Kennels		1			0.0004		1			0.21
Pets		0.56	0.41	0.77			0.91	0.53	1.55	
Age group ^c										
<6 months	15	1			<0.0001	12	1			<0.0001
>6 months		0.36	0.32	0.41			0.47	0.42	0.53	

^a Random effects negative binomial regression adjusted for diagnostic method.

^b Random effects negative binomial regression adjusted for region.

^c Conditional negative binomial regression.

^d Random effects negative binomial regression adjusted for region and diagnostic method.

diagnostic method and age group) were obtainable in only a minority of studies, these were treated as matched data and used for conditional negative binomial regression.

It can be seen that the major predictor for prevalence rate is the diagnostic method used, with standard microscopy being very poor compared to ELISA (226% higher), IFA (248%) and PCR (242%) in dogs. In cats, the relative advantage of these other methods appears to be even greater than is the case for dogs, ELISA (268%), IFA (375%), and PCR (351%). There is no convincing impact of region on *Giardia* prevalence in dogs, though in cats there is some impact, with prevalence being greater in more tropical countries, especially in South America than in the industrial North. In further analyses, prevalence was greater in symptomatic compared to asymptomatic individuals (161% for dogs and 194% for cats) and lower in animals >6 months old compared to animals <6 months (64% less for dogs and 53% less for cats). Domestic pets were also less likely to be positive than strays or animals kept in kennels (44% less for dogs and 9% less for cats), although for cats this was not statistically significant.

Given the important effect of detection method on estimated prevalence, we recalculated the random effects pooled prevalence for two subgroups: microscopy for one subgroup and the other three methods combined (ELISA, IFA and PCR) for the other subgroup. For dogs the pooled prevalence for microscopy was 11.6% (95% CI 10–13.2%) and for the other detection methods was 19.8% (95% CI 17.9–21.7%). The respective pooled prevalence results

for cats were 6.5% (95% CI 4.2–9.2%) and 15.9% (95% CI 13.5–18.4%), respectively.

4. Discussion

We have shown that *Giardia* prevalence rate in the faeces of both dogs and cats varies substantially from one study to another. The pooled prevalence rates were 15.2% and 12% for dogs and cats, respectively. However, there was substantial heterogeneity in both datasets. There was also evidence of publication bias that may lead to overestimated pooled prevalence. The age of the animal, whether or not it is a domestic pet and whether or not it was symptomatic for diarrhoea also affected the prevalence. The geographical continent had some effect with the industrial northern regions of Europe and North America having lower prevalence than the rest of the world, but this was not particularly significant.

When we further investigated the data, it was clear that the major factor driving reported prevalence rates was the detection method used. In particular, we have shown that microscopy performs poorly compared to other detection methods. However, we acknowledge that microscopy is not as standardised as the other methods and preparation/concentration steps can dramatically influence the sensitivity of the technique. For example, it has been shown that zinc sulphate flotation followed by microscopy can have similar performance as molecular detection methods (Paz e Silva et al., 2012). For this investigation, including

all the variants of microscopy would have increased the number of variables in the regression, thus preventing meaningful analyses. Therefore, we have chosen to group detection methods together irrespective of their methodological variation. Another issue related to comparing prevalence data is that different laboratories could apply distinct cut-off limits, particularly relevant for ELISA and IFA. This could potentially mean that discordant results can be obtained from two laboratories. For molecular targets, PCR sensitivity also depends on gene abundance (single versus multi-copy genes). Another aspect, that is relevant to all detection methods, is the quantity and quality of the pathogen material in the sample (Bouzid et al., 2008). All these limitations make a direct comparison of the performance of diagnostic tests a tricky task. This has been addressed through standardised protocols for the detection of pathogens of public health importance including *Giardia*.

Our conclusions on the relative sensitivity of the main diagnostic approaches are similar to those found by direct comparison showing that microscopy performed the poorest (Geurden et al., 2008). Like Geurden and colleagues, we found that IFA was more sensitive than ELISA for cats, however, the difference was marginal for dogs. The very different sensitivities of the newer diagnostic tests compared to microscopy raise the question of whether or not these more sensitive tests give a better indication of zoonotic risk to humans. This is not an easy question to answer even though the greater prevalence derived from the more sensitive tests would suggest greater risk, the additional positives would be expected to excrete fewer cysts and so pose less of a risk. In any event, the epidemiological evidence is that companion animals are not a major source of human giardiasis (Hunter and Thompson, 2005). Furthermore, given that dogs and cats often carry non-human infective *Giardia* assemblages, one has to be very cautious about extrapolating risk to humans based solely on prevalence data in animals (Ballweber et al., 2010).

Meta-regression is becoming more common in meta-analysis of randomised controlled trials and can provide valuable insights when there are no direct comparisons (Salanti et al., 2008). However, meta-regression techniques do not provide as strong evidence because they are observational rather than experimental in design. This criticism of the approach would not apply in regard to the analyses presented here, in part because the primary studies were all observational in nature. Another criticism could be the potential for confounding factors affecting the estimates of the impact of predictors on prevalence rates. Whilst this may have affected the estimates of the relative sensitivity of the different analytical methods to some degree, this is unlikely to have a particularly large impact. For the other predictors (symptoms, age group and origin), such confounding will have largely been eliminated by the conditional regression analysis.

In conclusion, we have shown that *Giardia* is common in dogs and to a lesser extent in cats. Studies based on direct microscopy will significantly underestimate prevalence compared to immune-based or PCR detection methods. This does not necessarily imply a major risk of zoonotic disease as many of the strains found in dogs and cats will be of assemblages that do not pose a particular risk of human

illness, however, this would need to be assessed by typing of positive samples.

Acknowledgements

This work was partially supported by the European Union Seventh Framework programme under the AQUA-VALENS project (Grant Agreement number 311846).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.vetpar.2014.12.011>.

References

- Ahmed, W.M., Mousa, W.M., Aboelhadid, S.M., Tawfik, M.M., 2014. Prevalence of zoonotic and other gastrointestinal parasites in police and house dogs in Alexandria, Egypt. *Vet. World* 7, 275–280.
- Alves, O.D.F., Gomes, A.G., Silva, A.C.D., 2005. Occurrence of endoparasites in dogs from Goiânia county, Goiás: comparison of diagnostic techniques. *Ciênc. Anim. Bras.* 6, 127–133.
- Amfim, A., Părvu, M., Băcescu, B., Simion, V.E., 2011. Estimation of canine intestinal parasites in Bucharest and their risk to public health. *Bull. UASVM Vet. Med.* 68, 26–30.
- Anderson, K.A., Brooks, A.S., Morrison, A.L., Reid-Smith, R.J., Martin, S.W., Benn, D.M., Peregrine, A.S., 2004. Impact of *Giardia* vaccination on asymptomatic *Giardia* infections in dogs at a research facility. *Can. Vet. J.* 45, 924–930.
- Arbabi, M., Hooshyar, H., 2009. Gastrointestinal parasites of stray cats in Khashan, Iran. *Trop. Biomed.* 26, 16–22.
- Arguedas Zeledón, D., Bitter, E., Oliveira, J., Romero, D.J.J., 2006. Prevalence of *Toxocara canis* and other gastrointestinal parasites in dogs treated at a veterinary clinic in San José, Costa Rica. *Ciênc. Vet. (Heredia)* 24, 137–150.
- Asano, K., Suzuki, K., Matsumoto, T., Sakai, T., Asano, R., 2004. Prevalence of dogs with intestinal parasites in Tochigi, Japan in 1979, 1991 and 2002. *Vet. Parasitol.* 120, 243–248.
- Bajer, A., Bednarska, M., Rodo, A., 2011. Risk factors and control of intestinal parasite infections in sled dogs in Poland. *Vet. Parasitol.* 175, 343–350.
- Ballweber, L.R., Panuska, C., Huston, C.L., Vasilopoulos, R., Pharr, G.T., Mackin, A., 2009. Prevalence of and risk factors associated with shedding of *Cryptosporidium felis* in domestic cats of Mississippi and Alabama. *Vet. Parasitol.* 160, 306–310.
- Ballweber, L.R., Xiao, L.H., Bowman, D.D., Kahn, G., Cama, V.A., 2010. Giardiasis in dogs and cats: update on epidemiology and public health significance. *Trends Parasitol.* 26, 180–189.
- Barutzki, D., Schaper, R., 2003. Endoparasites in dogs and cats in Germany 1999–2002. *Parasitol. Res.* 90 (Suppl. 3), S148–S150.
- Barutzki, D., Schaper, R., 2011. Results of parasitological examinations of faecal samples from cats and dogs in Germany between 2003 and 2010. *Parasitol. Res.* 109 (Suppl. 1), S45–S60.
- Batchelor, D.J., Tzannes, S., Graham, P.A., Wastling, J.M., Pinchbeck, G.L., German, A.J., 2008. Detection of endoparasites with zoonotic potential in dogs with gastrointestinal disease in the UK. *Transbound. Emerg. Dis.* 55, 99–104.
- Becker, A.C., Rohen, M., Epe, C., Schnieder, T., 2012. Prevalence of endoparasites in stray and fostered dogs and cats in Northern Germany. *Parasitol. Res.* 111, 849–857.
- Berrilli, F., D'Alfonso, R., Giangaspero, A., Marangì, M., Brandonisio, O., Kabore, Y., Gle, C., Cianfanelli, C., Lauro, R., Di Cave, D., 2012. *Giardia duodenalis* genotypes and *Cryptosporidium* species in humans and domestic animals in Cote d'Ivoire: occurrence and evidence for environmental contamination. *Trans. R. Soc. Trop. Med. Hyg.* 106, 191–195.
- Bianciardi, R., Papini, R., Giuliani, G., Cardini, G., 2004. Prevalence of *Giardia* antigen in stool samples from dogs and cats. *Rev. Méd. Vét.* 155, 417–421.
- Bissett, S.A., Stone, M.L., Malik, R., Norris, J.M., O'Brien, C., Mansfield, C.S., Nicholls, J.M., Griffin, A., Gookin, J.L., 2009. Observed occurrence of *Tritrichomonas foetus* and other enteric parasites in Australian cattery and shelter cats. *J. Feline Med. Surg.* 11, 803–807.

- Bouzid, M., Steverding, D., Tyler, K.M., 2008. Detection and surveillance of waterborne protozoan parasites. *Curr. Opin. Biotechnol.* 19, 302–306.
- Bryan, H.M., Darimont, C.T., Paquet, P.C., Ellis, J.A., Goji, N., Gouix, M., Smits, J.E., 2011. Exposure to infectious agents in dogs in remote coastal British Columbia: possible sentinels of diseases in wildlife and humans. *Can. J. Vet. Res.* 75, 11–17.
- Caccio, S.M., Thompson, R.C., McLauchlin, J., Smith, H.V., 2005. Unravelling *Cryptosporidium* and *Giardia* epidemiology. *Trends Parasitol.* 21, 430–437.
- Capari, B., Hamel, D., Visser, M., Winter, R., Pfister, K., Rehbein, S., 2013. Parasitic infections of domestic cats, *Felis catus*, in western Hungary. *Vet. Parasitol.* 192, 33–42.
- Capelli, G., Frangipane di Regalbono, A., Iorio, R., Pietrobelli, M., Paoletti, B., Giangaspero, A., 2006. *Giardia* species and other intestinal parasites in dogs in north-east and central Italy. *Vet. Rec.* 159, 422–424.
- Carlin, E.P., Bowman, D.D., Scarlett, J.M., Garrett, J., Lorentzen, L., 2006. Prevalence of *Giardia* in symptomatic dogs and cats throughout the United States as determined by the IDEXX SNAP *Giardia* test. *Vet. Ther.* 7, 199–206.
- Carollo, M.C.C., Amato Neto, V., Braz, L.M.A., Kim, D., 2001. Detection of *Cyclospora* sp. oocysts in the faeces of stray dogs in Greater São Paulo, São Paulo State, Brazil. *Revi. Soc. Bras. Med. Trop.* 34, 597–598.
- Cazorla Perfetti, D., Morales Moreno, P., 2013. Intestinal parasites of zoonotic importance in domiciliary canines of a rural village from Falcón state, Venezuela. *B. Malariol. Salud Amb.* 53, 19–28.
- Cirak, V.Y., Bauer, C., 2004. Comparison of conventional coproscopical methods and commercial coproantigen ELISA kits for the detection of *Giardia* and *Cryptosporidium* infections in dogs and cats. *Berl. Munch. Tierarztl. Wochenschr.* 117, 410–413.
- Claerebout, E., Casaert, S., Dalemans, A.C., De Wilde, N., Levecke, B., Vercruyse, J., Geurden, T., 2009. *Giardia* and other intestinal parasites in different dog populations in Northern Belgium. *Vet. Parasitol.* 161, 41–46.
- Coelho, W.M.D., do Amarante, A.F.T., de Soutello, R.V.G., Meireles, M.V., Bresciani, K.D.S., 2009. Ocorrência de parasitos gastrintestinais em amostras fecais de felinos no município de Andradina, São Paulo. *Rev. Bras. Parasitol. Vet., Jaboticabal* 18, 46–49.
- Coman, S., Dida, I.C., Bačescu, B., 2009. Incidence and treatment of the diarrhoeic syndrome with parasite aetiology in dogs and cats. *Rev. Sci. Parasitol.* 10, 106–111.
- Cotton, J.A., Beatty, J.K., Buret, A.G., 2011. Host–parasite interactions and pathophysiology in *Giardia* infections. *Int. J. Parasitol.* 41, 925–933.
- Covacin, C., Aucoin, D.P., Elliot, A., Thompson, R.C.A., 2011. Genotypic characterisation of *Giardia* from domestic dogs in the USA. *Vet. Parasitol.* 177, 28–32.
- Cummings, P., McKnight, B., 2004. Analysis of matched cohort data. *Stata J.* 4, 274–281.
- Dado, D., Montoya, A., Blanco, M.A., Miró, G., Saugar, J.M., Bailo, B., Fuentes, I., 2012. Prevalence and genotypes of *Giardia duodenalis* from dogs in Spain: possible zoonotic transmission and public health importance. *Parasitol. Res.* 111, 2419–2422.
- Dall'Agnol, L.P., Otto, M.A., Silva, A.S., Monteiro, d.S.G., 2010. Gastrointestinal parasites in naturally infected cats in the municipality of Santa Maria in Rio Grande do Sul, Brazil. *Acta Vet. Bras.* 4, 181–184.
- De Santis-Kerr, A.C., Raghavan, M., Glickman, N.W., Caldanaro, R.J., Moore, G.E., Lewis, H.B., Schantz, P.M., Glickman, L.T., 2006. Prevalence and risk factors for *Giardia* and *coccidia* species of pet cats in 2003–2004. *J. Feline Med. Surg.* 8, 292–301.
- Dubna, S., Langrova, I., Napravnik, J., Jankovska, I., Vadlejch, J., Pekar, S., Fechtner, J., 2007. The prevalence of intestinal parasites in dogs from Prague, rural areas, and shelters of the Czech Republic. *Vet. Parasitol.* 145, 120–128.
- Epe, C., Rehker, G., Schnieder, T., Lorentzen, L., Kreienbrock, L., 2010. *Giardia* in symptomatic dogs and cats in Europe – results of a European study. *Vet. Parasitol.* 173, 32–38.
- Farias, A., Silva, d.N.S., Oliveira, M.D., Rocha, J.B.S., Santos, L.B.K.R.D., 2013. Diagnosis of gastrointestinal parasites in dogs from Bom Jesus, Piauí, Brazil. *Rev. Acad. Ciênc. Agr. Ambient.* 11, 431–435.
- Feng, Y.Y., Xiao, L.H., 2011. Zoonotic potential and molecular epidemiology of *Giardia* species and giardiasis. *Clin. Microbiol. Rev.* 24, 110.
- Ferreira, F.S., Pereira-Baltasar, P., Parreira, R., Padre, L., Vilhena, M., Tavora Távira, L., Atougua, J., Centeno-Lima, S., 2011. Intestinal parasites in dogs and cats from the district of Evora, Portugal. *Vet. Parasitol.* 179, 242–245.
- Fontanarrosa, M.F., Vezzani, D., Basabe, J., Eiras, D.F., 2006. An epidemiological study of gastrointestinal parasites of dogs from Southern Greater Buenos Aires (Argentina): age, gender, breed, mixed infections, and seasonal and spatial patterns. *Vet. Parasitol.* 136, 283–295.
- Gates, M.C., Nolan, T.J., 2009. Endoparasite prevalence and recurrence across different age groups of dogs and cats. *Vet. Parasitol.* 166, 153–158.
- Geurden, T., Berkvens, D., Casaert, S., Vercruyse, J., Claerebout, E., 2008. A Bayesian evaluation of three diagnostic assays for the detection of *Giardia duodenalis* in symptomatic and asymptomatic dogs. *Vet. Parasitol.* 157, 14–20.
- Gharekhani, J., 2014. Study on gastrointestinal zoonotic parasites in pet dogs in Western Iran. *Turkiye Parazitol. Derg./Turkiye Parazitol. Dern. = Acta Parasitol. Turcica/Turkish Soc. Parasitol.* 38, 172–176.
- Gingrich, E.N., Scorza, A.V., Clifford, E.L., Olea-Popelka, F.J., Lappin, M.R., 2010. Intestinal parasites of dogs on the Galapagos Islands. *Vet. Parasitol.* 169, 404–407.
- Gizzi, A.B., Oliveira, S.T., Leutenegger, C.M., Estrada, M., Kozemjak, D.A., Stedile, R., Marcondes, M., Biondo, A.W., 2014. Presence of infectious agents and co-infections in diarrheic dogs determined with a real-time polymerase chain reaction-based panel. *BMC Vet. Res.* 10, 23.
- Gookin, J.L., Stebbins, M.E., Hunt, E., Burlone, K., Fulton, M., Hochel, R., Talaat, M., Poore, M., Levy, M.G., 2004. Prevalence of and risk factors for feline *Trichostrongylus axei* and *Giardia* infection. *J. Clin. Microbiol.* 42, 2707–2710.
- Gow, A.G., Gow, D.J., Hall, E.J., Langton, D., Clarke, C., Papasouliotis, K., 2009. Prevalence of potentially pathogenic enteric organisms in clinically healthy kittens in the UK. *J. Feline Med. Surg.* 11, 655–662.
- Gracenea, M., Gómez, M.S., Torres, J., 2009. Prevalence of intestinal parasites in shelter dogs and cats in the metropolitan area of Barcelona (Spain). *Acta Parasitol.* 54, 73–77.
- Guest, C.M., Stephen, J.M., Price, C.J., 2007. Prevalence of *Campylobacter* and four endoparasites in dog populations associated with hearing dogs. *J. Small Anim. Pract.* 48, 632–637.
- Gundlach, J.L., Sadzikowski, A.B., Stepien-Rukasz, H., Studzinska, M.B., Tomczuk, K., 2005. Comparison of some serological methods and coproscopic examinations for diagnosis of *Giardia* spp. invasion in dogs. *Pol. J. Vet. Sci.* 8, 137–140.
- Hackett, T., Lappin, M.R., 2003. Prevalence of enteric pathogens in dogs of north-central Colorado. *J. Am. Anim. Hosp. Assoc.* 39, 52–56.
- Hamnes, I.S., Gjerde, B.K., Robertson, L.J., 2007. A longitudinal study on the occurrence of *Cryptosporidium* and *Giardia* in dogs during their first year of life. *Acta Vet. Scand.* 49, 22.
- Himsworth, C.G., Skinner, S., Chaban, B., Jenkins, E., Wagner, B.A., Harms, N.J., Leighton, F.A., Thompson, R.C., Hill, J.E., 2010. Multiple zoonotic pathogens identified in canine feces collected from a remote Canadian indigenous community. *Am. J. Trop. Med. Hyg.* 83, 338–341.
- Hoopes, J.H., Polley, L., Wagner, B., Jenkins, E.J., 2013. A retrospective investigation of feline gastrointestinal parasites in western Canada. *Can. Vet. J.* 54, 359–362.
- Huber, F., Bomfim, T.C.B., Gomes, R.S., 2005. Comparison between natural infection by *Cryptosporidium* sp., *Giardia* sp. in dogs in two living situations in the West Zone of the municipality of Rio de Janeiro. *Vet. Parasitol.* 130, 69–72.
- Hunter, P.R., Thompson, R.C.A., 2005. The zoonotic transmission of *Giardia* and *Cryptosporidium*. *Int. J. Parasitol.* 35, 1181–1190.
- Inpankaew, T., Traub, R., Thompson, R.C., Sukthana, Y., 2007. Canine parasitic zoonoses in Bangkok temples. *Southeast Asian J. Trop. Med. Public Health* 38, 247–255.
- Itoh, N., Itagaki, T., Kawabata, T., Konaka, T., Muraoka, N., Saeki, H., Kanai, K., Chikazawa, S., Hori, Y., Hoshi, F., Higuchi, S., 2011a. Prevalence of intestinal parasites and genotyping of *Giardia intestinalis* in pet shop puppies in east Japan. *Vet. Parasitol.* 176, 74–78.
- Itoh, N., Kanai, K., Hori, Y., Hoshi, F., Higuchi, S., 2009. Prevalence of *Giardia intestinalis* and other zoonotic intestinal parasites in private household dogs of the Hachinohe area in Aomori prefecture, Japan in 1997, 2002 and 2007. *J. Vet. Sci.* 10, 305–308.
- Itoh, N., Kanai, K., Tominaga, H., Kawamata, J., Kaneshima, T., Chikazawa, S., Hori, Y., Hoshi, F., Higuchi, S., 2011b. *Giardia* and other intestinal parasites in dogs from veterinary clinics in Japan. *Parasitol. Res.* 109, 253–256.
- Itoh, N., Muraoka, N., Aoki, M., Itagaki, T., 2001. Prevalence of *Giardia lamblia* infection in household dogs. *Kansenshogaku Zasshi* 75, 671–677.
- Itoh, N., Muraoka, N., Kawamata, J., Aoki, M., Itagaki, T., 2006. Prevalence of *Giardia intestinalis* infection in household cats of Tohoku District in Japan. *J. Vet. Med. Sci.* 68, 161–163.
- Itoh, N., Muraoka, N., Saeki, H., Aoki, M., Itagaki, T., 2005. Prevalence of *Giardia intestinalis* infection in dogs of breeding kennels in Japan. *J. Vet. Med. Sci.* 67, 717–718.
- Jacobs, S.R., Forrester, C.P., Yang, J., 2001. A survey of the prevalence of *Giardia* in dogs presented to Canadian veterinary practices. *Can. Vet. J.* 42, 45–46.

- Jafari Shoorijeh, S., Sadjjadi, S.M., Asheri, A., Eraghi, K., 2008. *Giardia* spp. and *Sarcocystis* spp. status in pet dogs of Shiraz, Southern part of Iran. *Trop. Biomed.* 25, 154–159.
- Jaros, D., Zygnier, W., Jaros, S., Wedrychowicz, H., 2011. Detection of *Giardia intestinalis* assemblages A, B and D in domestic cats from Warsaw, Poland. *Pol. J. Microbiol.* 60, 259–263.
- Jiménez-Cardoso, E., Eligio-García, L., Cortés-Campos, A., Estrada, A.C., Pinto-Sagahón, M., Noguera-Estrada, C., 2010. The frequency of intestinal parasites in puppies from Mexican kennels. *Health* 2, 1316–1319.
- Joffe, D., Van Niekerk, D., Gagne, F., Gilleard, J., Kutz, S., Lobingier, R., 2011. The prevalence of intestinal parasites in dogs and cats in Calgary, Alberta. *Can. Vet. J.* 52, 1323–1328.
- Johansen, K.M., Castro, N.S., Lancaster, K.E., Madrid, E., Havas, A., Simms, J., Sterling, C.R., 2014. Characterization of *Giardia lamblia* genotypes in dogs from Tucson, Arizona using SSU-rRNA and beta-giardin sequences. *Parasitol. Res.* 113, 387–390.
- Katagiri, S., Oliveira-Sequeira, T.C., 2008. Prevalence of dog intestinal parasites and risk perception of zoonotic infection by dog owners in Sao Paulo State, Brazil. *Zoon. Public Health* 55, 406–413.
- Khademvatan, S., Abdizadeh, R., Rahim, F., Hashemitabar, M., Ghasemi, M., Tavalla, M., 2014. Stray cats gastrointestinal parasites and its association with public health in Ahvaz City, South Western of Iran. *Jundishapur J. Microbiol.* 7, e11079.
- Khalafalla, R.E., 2011. A survey study on gastrointestinal parasites of stray cats in northern region of Nile delta, Egypt. *PLOS ONE* 6, e20283.
- Kingsbury, D.D., Marks, S.L., Cave, N.J., Grahn, R.A., 2010. Identification of *Trichostrongylus foetus* and *Giardia* spp. infection in pedigree show cats in New Zealand. *New Zeal. Vet. J.* 58, 6–10.
- Klimpel, S., Heukelbach, J., Pothmann, D., Ruckert, S., 2010. Gastrointestinal and ectoparasites from urban stray dogs in Fortaleza (Brazil): high infection risk for humans? *Parasitol. Res.* 107, 713–719.
- Knaus, M., Rapti, D., Shukullari, E., Kusi, I., Postoli, R., Xhaxhiu, D., Silaghi, C., Hamel, D., Visser, M., Winter, R., Rehbein, S., 2014. Characterisation of ecto- and endoparasites in domestic cats from Tirana, Albania. *Parasitol. Res.* 113, 3361–3371.
- Kotloff, K.L., Nataro, J.P., Blackwelder, W.C., Nasrin, D., Farag, T.H., Panchalingam, S., Wu, Y., Sow, S.O., Sur, D., Breiman, R.F., Faruque, A.S., Zaidi, A.K., Saha, D., Alonso, P.L., Tamboura, B., Sanogo, D., Onwuchekwa, U., Manna, B., Ramamurthy, T., Kanungo, S., Ochieng, J.B., Omoro, R., Oundo, J.O., Hossain, A., Das, S.K., Ahmed, S., Qureshi, S., Quadri, F., Adegbola, R.A., Antonio, M., Hossain, M.J., Akinsola, A., Mandomando, I., Nhampossa, T., Acacio, S., Biswas, K., O'Reilly, C.E., Mintz, E.D., Berkeley, L.Y., Muhsen, K., Sommerfelt, H., Robins-Browne, R.M., Levine, M.M., 2013. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. *Lancet* 382, 209–222.
- Labarthe, N., Mendes-De-Almeida, F., Balbi, M., Salomão, M., Paiva, J., Crissiuma, A.L., Garcia, R., Miranda, d.C.N.C.M., 2008. Prevalence of *Giardia* in household dogs and cats in the State of Rio de Janeiro using the IDEXX SNAP® *Giardia* test. *Int. J. Appl. Res. Vet. Med.* 6, 200–206.
- Labruna, M.B., Pena, H.F.J., Souza, S.L.P., Pinter, A., Silva, J.C.R., Ragozo, A.M.A., Camargo, L.M.A., Gennari, S.M., 2006. Prevalence of endoparasites in dogs from the urban area of Monte Negro Municipality, Rondônia, Brazil. *Arq. Inst. Biol. (São Paulo)* 73, 183–193.
- Lane, S., Lloyd, D., 2002. Current trends in research into the waterborne parasite *Giardia*. *Crit. Rev. Microbiol.* 28, 123–147.
- Lavallén, C.M., Dopchiz, M.C., Lobianco, E., Hollmann, P., Denegri, G., 2011. Intestinal parasites of zoonotic importance in dogs from the District of General Pueyrredón (Buenos Aires, Argentina). *Rev. Vet.* 22, 19–24.
- Lefebvre, S.L., Waltner-Toews, D., Peregrine, A.S., Reid-Smith, R., Hodge, L., Arroyo, L.G., Weese, J.S., 2006. Prevalence of zoonotic agents in dogs visiting hospitalized people in Ontario: implications for infection control. *J. Hosp. Infect.* 62, 458–466.
- Li, J., Zhang, P., Wang, P., Alsarakibi, M., Zhu, H., Liu, Y., Meng, X., Li, J., Guo, J., Li, G., 2012. Genotype identification and prevalence of *Giardia duodenalis* in pet dogs of Guangzhou, southern China. *Vet. Parasitol.* 188, 368–371.
- Li, W., Liu, C., Yu, Y., Li, J., Gong, P., Song, M., Xiao, L., Zhang, X., 2013. Molecular characterization of *Giardia duodenalis* isolates from police and farm dogs in China. *Exp. Parasitol.* 135, 223–226.
- Little, S.E., Johnson, E.M., Lewis, D., Jaklitsch, R.P., Payton, M.E., Blagburn, B.L., Bowman, D.D., Moroff, S., Tams, T., Rich, L., Aucoin, D., 2009. Prevalence of intestinal parasites in pet dogs in the United States. *Vet. Parasitol.* 166, 144–152.
- Liu, J., Lee, S.E., Song, K.H., 2008. Prevalence of canine giardiasis in South Korea. *Res. Vet. Sci.* 84, 416–418.
- Lopez, J., Abarca, K., Paredes, P., Inzunza, E., 2006. Intestinal parasites in dogs and cats with gastrointestinal symptoms in Santiago, Chile. *Rev. Med. Chile* 134, 193–200.
- Lorenzini, G., Tasca, T., Carli, G.A.D., 2007. Prevalence of intestinal parasites in dogs and cats under veterinary care in Porto Alegre, Rio Grande do Sul, Brazil. *Braz. J. Vet. Res. Anim. Sci.* 44, 137–145.
- Lucio-Forster, A., Bowman, D.D., 2011. Prevalence of fecal-borne parasites detected by centrifugal flotation in feline samples from two shelters in upstate New York. *J. Feline Med. Surg.* 13, 300–303.
- Mancianti, F., Nardoni, S., Mugnaini, L., Zambernardi, L., Guerrini, A., Gazzola, V., Papini, R.A., 2014. A retrospective molecular study of select intestinal protozoa in healthy pet cats from Italy. *BioMed Res. Int.*
- Mark-Carew, M.P., Adesiyun, A.A., Basu, A., Georges, K.A., Pierre, T., Tilitz, S., Wade, S.E., Mohammed, H.O., 2013. Characterization of *Giardia duodenalis* infections in dogs in Trinidad and Tobago. *Vet. Parasitol.* 196, 199–202.
- Martinez-Carrasco, C., Berriatua, E., Garijo, M., Martinez, J., Alonso, F.D., de Ybanez, R.R., 2007. Epidemiological study of non-systemic parasitism in dogs in southeast mediterranean Spain assessed by coprological and post-mortem examination. *Zoon. Public Health* 54, 195–203.
- Martinez-Moreno, F.J., Hernandez, S., Lopez-Cobos, E., Becerra, C., Acosta, I., Martinez-Moreno, A., 2007. Estimation of canine intestinal parasites in Cordoba (Spain) and their risk to public health. *Vet. Parasitol.* 143, 7–13.
- McGlade, T.R., Robertson, I.D., Elliot, A.D., Thompson, R.C.A., 2003. High prevalence of *Giardia* detected in cats by PCR. *Vet. Parasitol.* 110, 197–205.
- McKenzie, E., Riehl, J., Banse, H., Kass, P.H., Nelson, S., Marks, S.L., 2010. Prevalence of diarrhea and enteropathogens in racing sled dogs. *J. Vet. Intern. Med.* 24, 97–103.
- Meireles, P., Montiani-Ferreira, F., Thomaz-Soccol, V., 2008. Survey of giardiasis in household and shelter dogs from metropolitan areas of Curitiba, Parana state, Southern Brazil. *Vet. Parasitol.* 152, 242–248.
- Mekaru, S.R., Marks, S.L., Felley, A.J., Choucha, N., Kass, P.H., 2007. Comparison of direct immunofluorescence, immunoassays, and fecal flotation for detection of *Cryptosporidium* spp. and *Giardia* spp. in naturally exposed cats in 4 Northern California animal shelters. *J. Vet. Intern. Med.* 21, 959–965.
- Mircean, V., Gyorke, A., Cozma, V., 2012. Prevalence and risk factors of *Giardia duodenalis* in dogs from Romania. *Vet. Parasitol.* 184, 325–329.
- Mircean, V., Gyorke, A., Jarca, A., Cozma, V., 2011. Prevalence of *Giardia* species in stool samples by ELISA in household cats from Romania and risk factors. *J. Feline Med. Surg.* 13, 479–482.
- Mircean, V., Titilincu, A., Vasile, C., 2010. Prevalence of endoparasites in household cat (*Felis catus*) populations from Transylvania (Romania) and association with risk factors. *Vet. Parasitol.* 171, 163–166.
- Miro, G., Mateo, M., Montoya, A., Vela, E., Calonge, R., 2007. Survey of intestinal parasites in stray dogs in the Madrid area and comparison of the efficacy of three anthelmintics in naturally infected dogs. *Parasitol. Res.* 100, 317–320.
- Mirzaei, M., 2010. Prevalence of stray dogs with intestinal protozoan parasites. *Am. J. Anim. Vet. Sci.* 5, 86–90.
- Mochizuki, M., Hashimoto, M., Ishida, T., 2001. Recent epidemiological status of canine viral enteric infections and *Giardia* infection in Japan. *J. Vet. Med. Sci.* 63, 573–575.
- Mohamed, A.S., Glickman, L.T., Camp Jr., J.W., Lund, E., Moore, G.E., 2013. Prevalence and risk factors for *Giardia* spp. infection in a large national sample of pet dogs visiting veterinary hospitals in the United States (2003–2009). *Vet. Parasitol.* 195, 35–41.
- Mohsen, A., Hossein, H., 2009. Gastrointestinal parasites of stray cats in Khashan, Iran. *Trop. Biomed.* 26, 16–22.
- Mosallanejad, B., Avizeh, R., Jalali, M.H.R., Alborzi, A.R., 2010a. Prevalence of *Giardia duodenalis* infection in household cats of Ah-vaz District, South-West of Iran. *Iran. J. Parasitol.* 5, 27–34.
- Mosallanejad, B., Avizeh, R., Jalali, M.H.R., Alborzi, A.R., 2010b. Antigenic detection of *Giardia duodenalis* in companion dogs of Ahvaz area, south-west of Iran. *Jundishapur J. Microbiol.* 3, 187–193.
- Mota, K.C.P., Gómez-Hernández, C., Rezende-Oliveira, K., 2014. Frequency of intestinal parasites in dog stool samples in a town of the Pontal do Triângulo region, Minas Gerais state, Brazil. *Rev. Patol. Trop.* 43, 219–227.
- Mukaratirwa, S., Singh, V.P., 2010. Prevalence of gastrointestinal parasites of stray dogs impounded by the Society for the Prevention of Cruelty to Animals (SPCA), Durban and Coast, South Africa. *J. S. Afr. Vet. Assoc.* 81, 123–125.
- Mundim, M.J., Rosa, L.A., Hortencio, S.M., Faria, E.S., Rodrigues, R.M., Cury, M.C., 2007. Prevalence of *Giardia duodenalis* and *Cryptosporidium* spp. in dogs from different living conditions in Uberlândia, Brazil. *Vet. Parasitol.* 144, 356–359.

- Mundim, M.J.S., Souza, S.Z., Hortêncio, S.M., Cury, M.C., 2003. Frequency of *Giardia* spp. shown by two diagnostic methods in faeces of dogs. *Arq. Bras. Med. Vet. Zoot.* 55, 770–773.
- Nareaho, A., Puomio, J., Saarinen, K., Jokelainen, P., Juselius, T., Sukura, A., 2012. Feline intestinal parasites in Finland: prevalence, risk factors and anthelmintic treatment practices. *J. Feline Med. Surg.* 14, 378–383.
- Natale, A., Regalbono, A.F., Zanellato, D., Cavalletto, G., Danesi, M., Capelli, P., Pietrobelli, G.M., 2007. Parasitological survey on stray cat colonies from the Veneto Region. *Vet. Res. Commun.* 31, 241–244.
- Neves, D., Lobo, L., Simoes, P.B., Cardoso, L., 2014. Frequency of intestinal parasites in pet dogs from an urban area (greater Oporto, northern Portugal). *Vet. Parasitol.* 200, 295–298.
- Nikolic, A., Dimitrijevic, S., Katic-Radivojevic, S., Klun, I., Bobic, B., Djurkovic-Djakovic, O., 2008. High prevalence of intestinal zoonotic parasites in dogs from Belgrade, Serbia. *Acta Vet. Hung.* 56, 335–340.
- Nikolić, A., Dimitrijević, S., Djurković-Djaković, O., Bobić, B., Maksimović-Mihajlović, O., 2002. Giardiasis in dogs and cats in the Belgrade area. *Acta Vet. (Beograd)* 52, 43–47.
- Oliveira-Sequeira, T.C., Amarante, A.F., Ferrari, T.B., Nunes, L.C., 2002. Prevalence of intestinal parasites in dogs from Sao Paulo State, Brazil. *Vet. Parasitol.* 103, 19–27.
- Olson, M.E., Leonard, N.J., Strout, J., 2010. Prevalence and diagnosis of *Giardia* infection in dogs and cats using a fecal antigen test and fecal smear. *Can. Vet. J.* 51, 640–642.
- Ortuño, A., Castellà, J., 2011. Intestinal parasites in shelter dogs and risk factors associated with the facility and its management. *Israel J. Vet. Med.* 66, 103–107.
- Ortuno, A., Scorza, V., Castella, J., Lappin, M., 2014. Prevalence of intestinal parasites in shelter and hunting dogs in Catalonia, Northeastern Spain. *Vet. J.* 199, 465–467.
- Overgaauw, P.A.M., van Zutphen, L., Hoek, D., Yaya, F.O., Roelfsema, J., Pinelli, E., van Knapen, F., Kortbeek, L.M., 2009. Zoonotic parasites in fecal samples and fur from dogs and cats in The Netherlands. *Vet. Parasitol.* 163, 115–122.
- Pablo, J.O., Chávez, V., Suárez, A.A., Pinedo, F.V., Falcón, R.P.N., 2012. *Giardia* spp. in dogs and children in rural communities of three districts of Puno, Peru. *Rev. Invest. Vet. Perú* 23, 462–468.
- Palmer, C.S., Thompson, R.C., Traub, R.J., Rees, R., Robertson, I.D., 2008. National study of the gastrointestinal parasites of dogs and cats in Australia. *Vet. Parasitol.* 151, 181–190.
- Paoletti, B., Otranto, D., Weigl, S., Giangaspero, A., Di Cesare, A., Traversa, D., 2011. Prevalence and genetic characterization of *Giardia* and *Cryptosporidium* in cats from Italy. *Res. Vet. Sci.* 91, 397–399.
- Papazahariadou, M., Founta, A., Papadopoulos, E., Chliounakis, S., Antoniadou-Sotiriadou, K., Theodorides, Y., 2007. Gastrointestinal parasites of shepherd and hunting dogs in the Serres Prefecture, Northern Greece. *Vet. Parasitol.* 148, 170–173.
- Papini, R., Giuliani, G., Gorini, G., Cardini, G., 2007. Survey of feline giardiasis by ELISA test in Italy. *Vet. Res. Commun.* 31, 297–303.
- Papini, R., Gorini, G., Spaziani, A., Cardini, G., 2005. Survey on giardiasis in shelter dog populations. *Vet. Parasitol.* 128, 333–339.
- Papini, R., Marangi, M., Mancianti, F., Giangaspero, A., 2009. Occurrence and cyst burden of *Giardia duodenalis* in dog faecal deposits from urban green areas: implications for environmental contamination and related risks. *Prev. Vet. Med.* 92, 158–162.
- Paris, J.K., Wills, S., Balzer, H.J., Shaw, D.J., Gunn-Moore, D.A., 2014. Enteropathogen co-infection in UK cats with diarrhoea. *BMC Vet. Res.* 10 (12 January 2014).
- Paz e Silva, F.M., Monobe, M.M., Lopes, R.S., Araujo Jr., J.P., 2012. Molecular characterization of *Giardia duodenalis* in dogs from Brazil. *Parasitol. Res.* 110, 325–334.
- Pinto, L.D., Marques, S.M.T., Bigatti, L.E., Araujo, F.A.P.d., 2007. Enteroparasites in dogs: prevalence and owners' knowledge about epidemiological factors. *Veterinaria em foco* 5, 10–15.
- Pipia, A.P., Varcasia, A., Tamponi, C., Sanna, G., Soda, M., Paoletti, B., Traversa, D., Scala, A., 2014. Canine giardiasis in Sardinia Island, Italy: prevalence, molecular characterization, and risk factors. *J. Infect. Dev. Countries* 8, 655–660.
- Pivoto, F.L., Lopes, L.F.D., Vogel, F.S.F., Botton, S., Sangioni, d.A.L.A., 2013. Occurrence of gastrointestinal parasites and parasitism risk factors in domestic cats in Santa Maria, RS, Brazil. *Ciênc. Rural* 43, 1453–1458.
- Polak, K.C., Levy, J.K., Crawford, P.C., Leutenegger, C.M., Moriello, K.A., 2014. Infectious diseases in large-scale cat hoarding investigations. *Vet. J.* 201, 189–195.
- Ponce-Macotela, M., Peralta-Abarca, G.E., Martinez-Gordillo, M.N., 2005. *Giardia intestinalis* and other zoonotic parasites: prevalence in adult dogs from the southern part of Mexico City. *Vet. Parasitol.* 131, 1–4.
- Prates, L., Pacheco, L.S., Kuhl, J.B., Dias, M.L.G.G., Araújo, S.M., Pupulin, A.R.T., 2009. Frequency of intestinal parasites in domiciled dogs from Maringá city, Brazil. *Arq. Bras. Med. Vet. Zoot.* 61, 1468–1470.
- Procter, T.D., Pearl, D.L., Finley, R.L., Leonard, E.K., Janecko, N., Reid-Smith, R.J., Weese, J.S., Peregrine, A.S., Sargeant, J.M., 2014. A cross-sectional study examining *Campylobacter* and other zoonotic enteric pathogens in dogs that frequent dog parks in three cities in south-western Ontario and risk factors for shedding of *Campylobacter* spp. *Zoon. Public Health* 61, 208–218.
- Quadros, R.M., Weiss, P.H.E., Ezequiel, G.W., Tamanho, R.B., Lepo, G., Silva, M.R., Silva Junior, d.C.R.J., Araujo, d.F.A.P., Miletti, d.L.C., 2013. Prevalence of *Giardia duodenalis* among dogs seized by the Center for Control of Zoonoses (CCZ) of the city of Lages, Santa Catarina, Brazil. *Health* 5, 119–124.
- Queen, E.V., Marks, S.L., Farver, T.B., 2012. Prevalence of selected bacterial and parasitic agents in feces from diarrheic and healthy control cats from Northern California. *J. Vet. Intern. Med.* 26, 54–60.
- Razmi, G.R., 2009. Survey of dogs' parasites in Khorasan Razavi Province, Iran. *J. Parasitol.* 4, 48–54.
- Riggio, F., Mannella, R., Ariti, G., Perrucci, S., 2013. Intestinal and lung parasites in owned dogs and cats from central Italy. *Vet. Parasitol.* 193, 78–84.
- Rimhanen-Finne, R., Enemark, H.L., Kolehmainen, J., Toropainen, P., Haninen, M.L., 2007. Evaluation of immunofluorescence microscopy and enzyme-linked immunosorbent assay in detection of *Cryptosporidium* and *Giardia* infections in asymptomatic dogs. *Vet. Parasitol.* 145, 345–348.
- Rinaldi, L., Maurelli, M.P., Musella, V., Veneziano, V., Carbone, S., Di Sarno, A., Paone, M., Cringoli, G., 2008. *Giardia* and *Cryptosporidium* in canine faecal samples contaminating an urban area. *Res. Vet. Sci.* 84, 413–415.
- Rufino, S.M., Fernandes, C.G.N., Moura, S.T., Grosz, d.L.C.B., 2002. Descriptive epidemiological study of giardiasis in dogs attended at the Veterinary Hospital of the University of Cuiaba, Mato Grosso State. *Rev. Bras. Med. Vet.* 24, 198–202.
- Salanti, G., Higgins, J.P.T., Ades, A.E., Ioannidis, J.P.A., 2008. Evaluation of networks of randomized trials. *Stat. Methods Med. Res.* 17, 279–301.
- Santin, M., Trout, J.M., Vecino, J.A., Dubey, J.P., Fayer, R., 2006. *Cryptosporidium*, *Giardia* and *Enterocytozoon bieneusi* in cats from Bogota (Colombia) and genotyping of isolates. *Vet. Parasitol.* 141, 334–339.
- Santos, F.A.G., Yamamura, d., Vidotto, M.H.O., Camargo, P.L.d., 2007. Occurrence of gastrointestinal parasites in dogs (*Canis familiaris*) with acute diarrhea from metropolitan region of Londrina, Paraná State, Brazil. *Semina: Ciênc. Agr. (Londrina)* 28, 257–268.
- Scaramozzino, P., Di Cave, D., Berrilli, F., D'Orazi, C., Spaziani, A., Mazzanti, S., Scholl, F., De Liberato, C., 2009. A study of the prevalence and genotypes of *Giardia duodenalis* infecting kennelled dogs. *Vet. J.* 182, 231–234.
- Schar, F., Inpankaew, T., Traub, R.J., Khieu, V., Dalsgaard, A., Chimnoi, W., Chhoun, C., Sok, D., Marti, H., Muth, S., Odermatt, P., 2014. The prevalence and diversity of intestinal parasitic infections in humans and domestic animals in a rural Cambodian village. *Parasitol. Int.* 63, 597–603.
- Schurer, J.M., Hill, J.E., Fernando, C., Jenkins, E.J., 2012. Sentinel surveillance for zoonotic parasites in companion animals in indigenous communities of Saskatchewan. *Am. J. Trop. Med. Hyg.* 87, 495–498.
- Scorza, A.V., Duncan, C., Miles, L., Lappin, M.R., 2011. Prevalence of selected zoonotic and vector-borne agents in dogs and cats in Costa Rica. *Vet. Parasitol.* 183, 178–183.
- Serra, C.M.B., Uchoa, C.M.A., Coimbra, R.A., 2003. Exame parasitológico de fezes de gatos (*Felis catus domesticus*) domiciliados e errantes da Região Metropolitana do Rio de Janeiro, Brasil. *Rev. Soc. Bras. Med. Trop.* 36, 331–334.
- Shikha, S., Katoch, R., Anish, Y., Rajesh, G., 2013. *Giardia* prevalence in pet dogs in Jammu, India. *Vet. Pract.* 14, 181–182.
- Shukla, R., Giraldo, P., Kraliz, A., Finnigan, M., Sanchez, A.L., 2006. *Cryptosporidium* spp. and other zoonotic enteric parasites in a sample of domestic dogs and cats in the Niagara region of Ontario. *Can. Vet. J.* 47, 1179–1184.
- Smith, A.F., Semeniuk, C.A., Kutz, S.J., Massolo, A., 2014. Dog-walking behaviours affect gastrointestinal parasitism in park-attending dogs. *Parasit. Vectors* 7, 429.
- Sokolow, S.H., Rand, C., Marks, S.L., Drazenovich, N.L., Kather, E.J., Foley, J.E., 2005. Epidemiologic evaluation of diarrhea in dogs in an animal shelter. *Am. J. Vet. Res.* 66, 1018–1024.
- Solarczyk, P., Majewska, A.C., 2010. A survey of the prevalence and genotypes of *Giardia duodenalis* infecting household and sheltered dogs. *Parasitol. Res.* 106, 1015–1019.
- Soriano, S.V., Pierangeli, N.B., Rocchia, I., Bergagna, H.F., Lazzarini, L.E., Celescinco, A., Saiz, M.S., Kossman, A., Contreras, P.A., Arias, C.,

- Basualdo, J.A., 2010. A wide diversity of zoonotic intestinal parasites infects urban and rural dogs in Neuquen, Patagonia, Argentina. *Vet. Parasitol.* 167, 81–85.
- Sotelo, P.H., Chávez, V., Casas, A.A., Pinedo, E.V., Falcón, R.P.N., 2013. Giardiasis and *Cryptosporidiosis* in dogs of the western area of Metropolitan Lima. *Rev. Invest. Vet. Perú* 24, 353–359.
- Spada, E., Proverbio, D., Della Pepa, A., Domenichini, G., Bagnagatti De Giorgi, G., Traldi, G., Ferro, E., 2013. Prevalence of faecal-borne parasites in colony stray cats in northern Italy. *J. Feline Med. Surg.* 15, 672–677.
- Spain, C.V., Scarlett, J.M., Wade, S.E., McDonough, P., 2001. Prevalence of enteric zoonotic agents in cats less than 1 year old in Central New York State. *J. Vet. Intern. Med.* 15, 33–38.
- Suzuki, J., Murata, R., Kobayashi, S., Sadamasu, K., Kai, A., Takeuchi, T., 2011. Risk of human infection with *Giardia duodenalis* from cats in Japan and genotyping of the isolates to assess the route of infection in cats. *Parasitology* 138, 493–500.
- Szabová, E., Juriš, P., Miterpáková, M., Antolová, D., Papajová, I., Šefčíková, H., 2007. Prevalence of important zoonotic parasites in dog populations from the Slovak Republic. *Helminthologia* 44, 170–176.
- Szénási, Z., Marton, S., Kucsera, I., Táncoz, B., Horváth, K., Orosz, E., Lukács, Z., Szeidemann, Z., 2007. Preliminary investigation of the prevalence and genotype distribution of *Giardia intestinalis* in dogs in Hungary. *Parasitol. Res.* 101, S145–S152.
- Thompson, R.C.A., Palmer, C.S., O'Handley, R., 2008. The public health and clinical significance of *Giardia* and *Cryptosporidium* in domestic animals. *Vet. J.* 177, 18–25.
- Traub, R.J., Inpankaew, T., Reid, S.A., Sutthikornchai, C., Sukthana, Y., Robertson, I.D., Thompson, R.C.A., 2009. Transmission cycles of *Giardia duodenalis* in dogs and humans in temple communities in Bangkok – a critical evaluation of its prevalence using three diagnostic tests in the field in the absence of a gold standard. *Acta Trop.* 111, 125–132.
- Traub, R.J., Robertson, I.D., Irwin, P., Mencke, N., Monis, P., Thompson, R.C., 2003. Humans, dogs and parasitic zoonoses – unravelling the relationships in a remote endemic community in northeast India using molecular tools. *Parasitol. Res.* 90 (Suppl. 3), S156–S157.
- Tseng, Y.C., Ho, G.D., Chen, T.T., Huang, B.F., Cheng, P.C., Chen, J.L., Peng, S.Y., 2014. Prevalence and genotype of *Giardia duodenalis* from faecal samples of stray dogs in Hualien city of eastern Taiwan. *Trop. Biomed.* 31, 305–311.
- Tysnes, K., Gjerde, B., Nødtvedt, A., Skancke, E., 2011. A cross-sectional study of *Tritrichomonas foetus* infection among healthy cats at shows in Norway. *Acta Vet. Scand.* 53 (20 June 2011).
- Tzannes, S., Batchelor, D.J., Graham, P.A., Pinchbeck, G.L., Wastling, J., German, A.J., 2008. Prevalence of *Cryptosporidium*, *Giardia* and *Isospora* species infections in pet cats with clinical signs of gastrointestinal disease. *J. Feline Med. Surg.* 10, 1–8.
- Uehlinger, F.D., Greenwood, S.J., McClure, J.T., Conboy, G., O'Handley, R., Barkema, H.W., 2013. Zoonotic potential of *Giardia duodenalis* and *Cryptosporidium* spp. and prevalence of intestinal parasites in young dogs from different populations on Prince Edward Island, Canada. *Vet. Parasitol.* 196, 509–514.
- Upjohn, M., Cobb, C., Monger, J., Geurden, T., Claerebout, E., Fox, M., 2010. Prevalence, molecular typing and risk factor analysis for *Giardia duodenalis* infections in dogs in a central London rescue shelter. *Vet. Parasitol.* 172, 341–346.
- Vasilopoulos, R.J., Rickard, L.G., Mackin, A.J., Pharr, G.T., Huston, C.L., 2007. Genotypic analysis of *Giardia duodenalis* in domestic cats. *J. Vet. Intern. Med.* 21, 352–355.
- Veenemans, J., Mank, T., Ottenhof, M., Baidjoe, A., Mbugi, E.V., Demir, A.Y., Wielders, J.P.M., Savelkoul, H.F.J., Verhoef, H., 2011. Protection against diarrhea associated with *Giardia intestinalis* is lost with multi-nutrient supplementation: a study in Tanzanian children. *Plos Neglect. Trop. D.* 5.
- Volotão, A.C., Costa-Macedo, L.M., Haddad, F.S.M., Brandão, A., Peralta, J.M., Fernandes, O., 2007. Genotyping of *Giardia duodenalis* from human and animal samples from Brazil using β -giardin gene: a phylogenetic analysis. *Acta Trop.* 102, 10–19.
- Wang, A., Ruch-Gallie, R., Scorza, V., Lin, P., Lappin, M.R., 2012. Prevalence of *Giardia* and *Cryptosporidium* species in dog park attending dogs compared to non-dog park attending dogs in one region of Colorado. *Vet. Parasitol.* 184, 335–340.
- Yagoob, G., Bahman, K., 2014. Prevalence of intestinal protozoan parasites in stray dogs of Tabriz city, Iran. *Ind. J. Fundam. Appl. Life Sci.* 4, 20–24.
- Yang, D., Zhang, Q., Zhang, L., Dong, H., Jing, Z., Li, Z., Liu, J., 2014. Prevalence and risk factors of *Giardia duodenalis* in dogs from China. *Int. J. Environ. Health Res.*, 1–7.
- Yoshiuchi, R., Matsubayashi, M., Kimata, I., Furuya, M., Tani, H., Sasai, K., 2010. Survey and molecular characterization of *Cryptosporidium* and *Giardia* spp. in owned companion animal, dogs and cats, in Japan. *Vet. Parasitol.* 174, 313–316.
- Zajac, A.M., Johnson, J., King, S.E., 2002. Evaluation of the importance of centrifugation as a component of zinc sulfate fecal flotation examinations. *J. Am. Anim. Hosp. Assoc.* 38, 221–224.
- Zanzani, S.A., Gazzonis, A.L., Scarpa, P., 2014. Intestinal Parasites of Owned Dogs and Cats from Metropolitan and Micropolitan Areas: Prevalence, Zoonotic Risks, and Pet Owner Awareness in Northern Italy. *pp.* 696508.