Canine helminthiases and associated risk factors in Kigali city, Rwanda

Pie Ntampaka (✉ piusynt@gmail.com)

University of Rwanda <https://orcid.org/0000-0001-5605-1091>

François Niragire

University of Rwanda

Philip Njeru Nyaga

University of Nairobi

Gervais Habarugira

University of Rwanda

Research article

Keywords: dogs, helminths, ancylostomosis, toxocariosis, prevalence, risk factors, Kigali, Rwanda

Posted Date: November 11th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-26155/v3>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: Canine helminthiases pose a public health risk to humans and livestock. However, the prevalence of canine helminthiases in Rwanda is unknown. This study aimed to determine the prevalence of canine helminthiases and to identify the associated risk factors in Kigali city. A cross-sectional study involved 93 dogs selected across Kigali city. Faecal samples were collected from apparently healthy dogs and helminth eggs were identified and quantified under microscope using McMaster technique. Risk factors for canine helminthiases were analysed by multivariable binary logistic regression analysis.

Results: The overall prevalence of intestinal helminthiases in dogs was 39.8%, 95% CI: 29.84- 49.73. The most prevalent species was *Ancylostoma spp* with 32.3%, 95% CI: 22.76-41.76. About 38.7% and 3.4% (n= 31) of dogs having ancylostomosis and toxocarosis had high egg counts per gram of faeces (≥ 550) each. Logistic regression analysis showed that dog's age, dog feeding practices and location were significantly associated with the prevalence of canine helminthiases. Compared to dogs aged < 1 year, the adjusted odds ratio (AOR) of developing helminthiases was more than 10 times higher for dogs aged between 1- 2.5 years (AOR=10.310; 95% CI: 1.557- 68.288), more than 5 times greater for dogs aged between 2.5-5 years, and more than 7 times greater for dogs that were at least 5 years old (AOR=7.543; 95% CI: 1.1360.101). Furthermore, the AOR was more than 5 times higher (AOR=5.41; 95% CI: 1.28- 22.87) for dogs fed on raw animal origin supplements, leftovers from family food and restaurants and more than 13 times higher (AOR=13.581; 95% CI: 2.194-84.050) for dogs that ate leftovers from household food and scavenged compared to those that ate food prepared for them, respectively.

Conclusions: All the identified helminths including *Ancylostoma spp*, *Toxocara canis*, and tapeworms are zoonotic, and they pose a public health risk to humans. There is an urgent need of increasing the awareness among pet owners on the role of dogs in transmitting zoonotic helminthiases to other animals and to humans. The control of zoonotic helminthiases in dog population should focus on taking appropriate measures to promote hygienic dog feeding practices at all ages.

Background

Dogs play a considerable role in helping the man to improve the quality of life [1]. It has been demonstrated that pet dog owners are healthier than non-owners [2][3]. Pet dogs can help people under stressful conditions in enjoying their recreation and curing some pathological conditions such as high blood pressure [4]. In addition, people can own dogs for various reasons such as business, hunting, herding livestock, and guarding. Dogs also offer a variety of services such as helping the disabled live independently, search and rescue missions as well sniffing drugs and explosive [5]. Although the dog has become an indispensable companion of the man, it also constitutes a potential source of a variety of human infections [1].

Dogs can harbour parasitic infections that can be transmitted to livestock and humans including helminths and protozoa [6][7]. Ascarids and Ancylostomatids have been repeatedly reported to be the main helminths of dogs and cats with a global significance [8]. Dogs contract ancylostomosis through

skin penetration or oral ingestion of larvae. Oral transmission occurs through ingesting milk or paratenic hosts or suckling [9].

Canine toxocarosis can be transmitted horizontally or vertically, that is through ingesting earthworms, milk and soil contaminated with viable embryonated eggs or direct maternal foetal transmission during gestation [10]. Human zoonotic helminthiasis is transmitted directly or indirectly via an infected dog or ingestion of contaminated items [11]. Studies conducted around the world reported canine helminthiasis prevalence that varies between 5.9 % and 75.26% [12][13].

A wide range of factors can influence prevalence of helminthiasis in dogs. These factors can be intrinsic such as age, sex and breed or extrinsic like feeding, environment, accuracy of testing, regular deworming and geographical location [14][15][16][13][17]. The control of helminthiasis in dogs consists of proper hygiene, regular preventive deworming and treatment of clinically ill individuals [12][18]. However, misuse of anthelmintic drugs may lead to anthelmintic resistance in the treatment of worms infections in both animals and humans [12]. Anthelmintic resistance is primarily prevented through laboratory testing based treatment and respect of drug dosage [8].

Despite that canine helminthiasis are a public and a one health concern; there are no reports on canine helminthiasis in Rwanda. The aim of this study was to determine the prevalence of intestinal helminths in dogs and associated risk factors in Kigali, Rwanda.

Results

Characteristics of study dogs

Faecal samples were taken from 93 apparently healthy dogs from different locations and of different ages, sex and breeds. Among sampled dogs, some were regularly or irregularly dewormed. Some dogs were scavengers or fed on food prepared for them or leftovers from household food or restaurants. Also, some dogs were restricted while others were not restricted. The occurrence of intestinal helminths in study dogs is indicated (Table 1).

Table 1. Prevalence of various helminths in analysed faecal samples

Categories of helminths	Number of infected dogs	Percent (%)	95% CI for percentage	
Lower limit	Upper limit			
<i>Ancylostoma spp</i>	30	32.3	22.757	41.759
Tapeworms	6	6.5	1.459	11.445
<i>Toxocara canis</i> + <i>Ancylostoma spp</i>	1	1.1	-1.021	3.171
Total	37	39.8	29.837	49.733

The prevalence of helminthiases in dogs was 39.8%, 95% CI: 29.84-49.73. The predominant species was *Ancylostoma spp* with 32.3%; 95% CI: 22.757- 41.759. Of all infected dogs, 97.3% (36/37) were parasitised with one category of helminths whilst 2.7% were infected with two categories of helminths (Table 1). Parasitic load in dogs suffering from ancylostomosis and toxocarosis in Kigali city, Rwanda is shown (Fig. 1).

Chi-square tests of the associations of the occurrence of canine helminthiases with the selected potential risk factors in Kigali city and corresponding p-values are presented in Table 2. All considered risk factors, namely, deworming frequency, feeding practices, control of dog movements; breed, age, sex and location (district) were not statistically significant factors for canine helminthiases in dogs at 5% level of significance.

Table 2. Distribution of canine helminthiases and chi-square tests of its association with the selected potential risk factors in Kigali city

	Canine helminths	P-Value	
Sample characteristics	Present (%)	Absent (%)	Total (%)
Deworming frequency	0.588		
Never	23(24.7)	27(29.0)	50 (53.8)
Once to twice a year	4 (4.3)	10(10.8)	14 (15.1)
At least three times per year	3 (3.2)	5(5.4)	8 (8.6)
Irregularly	7 (7.5)	14 (15.1)	21 (22.6)
Total	37 (39.8)	56 (60.2)	93 (100)
Feeding practices	0.153		
Food prepared for dogs	9 (9.7)	21 (22.6)	30 (32.3)
Raw animal origin supplements, leftovers from household family food and restaurants	19 (20.4)	29 (31.2)	48 (51.6)
Scavenging and leftovers from household food	9 (9.7)	6 (6.5)	15 (16.1)
Total	37 (39.8)	56 (60.2)	93 (100)
Control of movements	0.407		
Non-restricted	15 (16.1)	18 (19.4)	33 (35.5)
Restricted	22 (23.7)	38 (40.9)	60 (64.5)
Total	37 (39.8)	56 (60.2)	93 (100)
Breed	0.949		
Local	11 (11.8)	17 (18.3)	28 (30.1)
Pure or cross	26 (28)	39 (41.9)	65 (69.9)
Total	37 (39.8)	56 (60.2)	93 (100)
Age	0.140		

<1 year	2 (2.2)	12 (12.9)	14(15.1)
1-2.5 years	14 (15.1)	13 (14)	27 (29)
2.5-5 years	12(12.9)	17(18.3)	29(31.2)
Overs 5 years	9(9.7)	14(15.1)	23(24.7)
Total	37(39.8)	56(60.2)	93(100)
Sex	0.791		
Female	28(30.1)	15(16.1)	24(25.8)
Male	9(9.7)	41(44.1)	69(74.2)
Total	37(39.8)	56(60.2)	93 (100)
Study district			0.054
Nyarugenge	13(14)	34(36.6)	47(50.5)
Gasabo	10(10.8)	9(9.7)	19(20.5)
Kicukiro	14(15.1)	13(14)	14(29)
Total	37(39.8)	56(60.2)	93(100)

A decision on which variable to include in a multivariate analysis can depend on different criteria [19] [20] [21]. In the present study, all the potential risk factors for which chi-square tests p-values were below 0.25 were considered for the subsequent multivariable logistic regression analysis, namely feeding practices, dog's age and location (district).

Table 3. Factors influencing helminthic infections among dogs in Kigali city

Variable	Categories	Adjusted Odds Ratio (AOR)	95% C.I. for AOR
Lower	Upper		
Dog feeding practices	Food prepared for dogs	1	Reference
Raw animal origin supplements, leftovers from household food and restaurants	5.415	1.282	22.874
Scavenging and leftovers from household food	13.581	2.194	84.050
Dog's age	<1 year old	1	Reference
1-2.5 years old	10.310	1.557	68.288
2.5-5 years old	5.257	0.849	32.566
At least 5 years old	7.543	1.136	50.101
Location	Nyarugenge	1	Reference
Gasabo	10.830	2.355	49.814
Kicukiro	8.191	1.842	36.418
	Constant	0.010	

The results in table 3 show that dog's age, dog feeding practices, and dog location (district) were significantly associated with the prevalence of canine helminthiasis in Kigali City. The adjusted odds ratio (AOR) of having helminthic infection was more than 10 and 7 times higher for dogs that were aged 1-2.5 years and at least 5 years, respectively, compared to those that were younger than one year old. The AORs of infection were about 11 and more than 8 times higher in dogs located in Gasabo and Kicukiro districts, respectively than dogs located in Nyarugenge district. Dog feeding practices were also statistically significant.

Specifically, the AOR was more than 5 times higher (AOR=5.415; 95% CI: 1.282-22.87) for dogs fed on raw animal origin supplements, leftovers from family food and restaurants compared to those that were fed on food prepared for them. Further, the AOR was more than 13 times higher for dogs that ate leftovers from household food and scavenged (AOR=13.581; 95% CI: 2.194-84.050) compared to those that ate food prepared for them.

Discussion

In this study, the prevalence of canine helminthiasis in Kigali city was 39.8%. The dog's age (1 to 2.5 years old and at least 5 years old), location and feeding practices were statistically significant risk factors associated with the canine helminthiasis. The prevalence of canine helminthiasis in the present study

was lower but comparable to 51.7% reported by Idika et al. [22] in Nigeria. However, it was considerably lower than 75.26% and 91.4% reported in Ethiopia and Gabon [13] [23], respectively. Management practices and climatic conditions might have influenced difference in prevalence in these various studies. In this study, 83.9% of dogs ate food provided by the owners and the AOR of developing helminthiasis was more than 13 times higher for dogs that ate leftovers from household food and scavenged compared to those of which ate food prepared for them. Similarly, Abere et al. [13] reported high prevalence of helminthiasis (82.2%) in dogs that ate uncooked food. Besides, Abere et al. [13] conducted their study in Bahir Dar town, and the latter borders lake Tana and Blue Nile. The influence of these waterbodies on the weather of the region would influence the biology of helminths.

This study prevalence of *Ancylostoma spp* (32.3%) was comparable to 34.8% reported in Gabon [23]. However, it was higher than 24.6% reported in Nigeria [24], and lower than 93.8% reported in Zaïre (currently the Democratic Republic of Congo) [25] Difference in prevalence may be related to management practices and accuracy in coprological testing.

For instance, the majority of dogs involved in the study by Schandevyl et al. [25] in the Democratic Republic of Congo were not properly looked after and they all were in poor condition. Furthermore, Schandevyl et al. [25] performed both McMaster technique and larval culturing to detect *Ancylostoma spp*. Different species of *Ancylostoma* can infect dogs including *A. caninum*, *A. braziliense*, *A. ceylanicum* and *Uncinaria stenocephala* [26]. Of these, *A. braziliense*, *A. caninum* and *U. stenocephala* can cause cutaneous larva migrans (sand-worm disease) in humans, while *A. ceylanicum* is able to cause eosinophilic enteritis. Similarly, *A. caninum* has been reported to cause eosinophilic enteritis, but it rarely matures into adult in human small intestine [27][28].

Studies conducted in Rwanda reported human ancylostomosis prevalence that varies between 6.33% and 33% [29][30]. In this study, 38.7% (12/31) of dogs that were infected with *Ancylostoma* had a high level of infection (EPG $\geq$ 550) and developed mono-infection caused by *Ancylostoma spp*. These dogs could shed a high number of the eggs in the environment and potentially put people at risk of contracting hookworm disease. Given the challenges to distinguish species of *Ancylostoma* based on egg morphometry and that a host can be parasitised by several species concurrently [26], the investigation of human ancylostomosis in Rwanda should take into consideration the zoonotic aspect, thus, the collection of information about pet ownership by human patients could guide the diagnosis.

The prevalence of cestodes (6.5) was lower than 8.6 % reported by Davoust et al. [23] in Gabon.

It was however higher than 2.7% reported by Schandevyl et al. [25] in the Democratic Republic of Congo. Dogs can harbour zoonotic cestodes, among others, *Echinococcus spp* and *Dipylidium caninum* [27]. The prevalence of *Toxocara canis* in the present study was 1%; lower than 9.8% reported by Ayinmode et al. [24] in Nigeria. *Toxocara canis* antibodies have been detected in people across Africa.

For instance, two previous studies conducted in preschool children aged between 9 months to 5 years old in Nigeria and in children aged 1-15 years old in Ghana detected *Toxocara canis* antibodies in 37.3% and

53.5% of the study children, respectively [31][32]. Further, one study conducted in various groups of professionals in Egypt detected anti-*T. canis* antibodies in 24% of the professionals [33]. Although there are no published data about human toxocariasis in Rwanda, the dog suffering from *Toxocarosis* and *Ancylostomosis* in this study, had an EPG of 750 for *Toxocara canis*. The high level of infection in tested dog (EPG $\geq$ 550) suggests that the dog could shed a high number of eggs in the environment and potentially put people at risk of developing toxocariasis.

Similar to a previous study by Idika et al. [22] in Nigeria, this study found that dog's age correlates positively with the prevalence of helminthiases (all odds ratios increase for age groups above 1 year. The present study also found a direct correlation between dog's location and the prevalence of canine helminthiases. Comparable to a study by Abere et al. [13] in Ethiopia, we found that feeding practices positively correlate with the prevalence of canine helminthiases.

have impacted the prevalence of canine helminthiases. Thus, the data in this study is a snapshot prevalence which may not necessarily represent the true burden of canine helminthiases. A kinetic study could shed some light on the prevalence and the dynamics of the helminthiases in dogs. Due to limited resources, researchers could not fully investigate the main canine helminths.

Further studies using molecular laboratory technique would be most welcome. The results of the binary logistic regression analysis showed unusually wide 95% confidence intervals of the odds ratios, especially for the dog's age, and location. This can largely be attributed to excessively small sample sizes for some age groups and districts as well as inconsistency in location data [34].

For example, the sample of infected dogs that were aged < 1 year and ≥ 5 years were only 2 and 9 dogs, respectively. Consistency in location data also appears to be a cause of wide confidence intervals for district covariate. The district of Gasabo had smaller samples for both infected and non-infected dogs.

Conclusion

All the identified helminths including *Ancylostoma spp*, *Toxocara canis*, and tapeworms are zoonotic, and they pose a public health risk to humans. There is an urgent need of increasing the awareness among pet owners on the role of dogs in transmitting zoonotic helminthiases to other animals and to humans. The control of zoonotic helminthiases in dog population should focus on taking appropriate measures to promote hygienic dog feeding practices at all ages.

Methods

Study sites

This study was carried out in Kigali city, the capital city of Rwanda from September 2016 to March 2017. Kigali city is administratively subdivided into three Districts and each district is in turn subdivided into administrative sectors [35]. The present study covered nine sectors that selected from the three districts

of Kigali city, each district was represented by three sectors. Figure 2 shows the map of Kigali City with district and sector level boundaries.

Study design and sample size

This cross-sectional study involved collecting data on management practices and faecal samples from dogs. Sample size was determined based on dogs population of 18,117 reported in 2016 [36]. The number of dogs in Kigali represented 2,157, thus 11.9% of the national dog population [37]. The population of dogs in the 9 selected sectors was 782. Due to lack of previous studies on canine helminthiases in Rwanda, the prevalence of helminthiases in dogs was assumed to be 50%.

Based on previous population-based health studies such as Rwanda demographic and health survey where the response rate has generally remained above 95% [38], we expected a relatively high response rate. Considering the scarcity of studies involving dog's health in Rwanda, and also considering that this study was conducted in the capital where most of people are relatively busy and away from homes during daytime, we increased the sample size by 10% to cater for possible non-response [39][40]. The minimal sample size (n) of dogs needed for testing hypothesis on risk factors of helminthiases in the present study was thus estimated using Cochran's formula for determining sample size for proportions [41], as follows:

See formula 1 in the supplementary files section.

Where N is the population size and e is the level of precision. Adjusting for 10% non-response rate (9 additional dogs), the present study targeted an effective sample of 101 dogs. This study sample was selected through a two-stage sampling procedure. In the first stage, we randomly selected three administrative sectors from each of the three districts of Kigali City. Thus, nine sectors were randomly selected across Kigali City, namely, Gatenga, Niboye and Kicukiro in Kicukiro district; Kacyiru, Kimironko and Gisozi in Gasabo district; and Mageragere, Nyamirambo and Kigali in Nyarugenge district. Based on district-level registers for dog population, which showed households where dogs were kept, a listing of all dogs for each of the selected sectors was done and it served as a sampling frame for this study.

In the second stage, systematic random sampling was applied to choose households owning dogs from constructed lists that were available at sector-level. Considering the sampling frame size, sampling interval i was determined to be $2157/101=21$. We randomly selected the first household that owned a dog and then we considered households at a regular interval of size 21 on the list until the target sample size was achieved. Given some households owned many dogs; only one dog per household was randomly selected for data collection.

Data collection

Data were successfully collected from 93 dogs and a questionnaire was used to collect data on dogs (age, sex, breeds and location), and on dog keeping practices (frequency of deworming, feeding practices and control of dog movements) (see additional file 1). Faecal samples were collected directly from the

rectum using a gloved finger and kept in faecal jars. All samples were stored in a cool box and were analysed at the laboratories of the Rwanda Agriculture and Animal Resources Development Board (RAB).

Faecal analysis

The analysis was done on the day sampling using the McMaster technique as previously described by Hansen and Perry [42]. The preparation of float fluid involved dissolving sodium chloride (Park Scientific Limited, UK) in tap water [43]. Cestodes, either worms or segments were detected in fresh faecal samples with the naked eye at time of the collection and they were identified based on a protocol by Baron; Ballweber [44][9]. Various nematode eggs were identified by examining the sample under the light microscope at 10x magnification based on shape, thickness of shell and presence of morulae [45].

Data processing and analysis

Data were entered and then analysed in the IBM SPSS Statistics for windows, version 20. EPG of faeces were obtained by multiplying the number of eggs by a factor of 50 as previously described by Hansen and Perry [42].

The infection was quantified by EPG which was grouped into low infection (50-100 EPG), moderate infection (150-500 EPG) and high infection (≥ 550 EPG) [46]. The analysis of faecal samples resulted into a binary response variable that indicated whether a sampled dog was infected or not infected. These data were used to determine the infection prevalence. To investigate associations between selected factors and prevalence of canine helminthiases, data were analysed using a multivariable binary logistic regression model as described by Peng and So [47]. The 95% confidence intervals for the AORs were used to assess the significance and direction of the associations.

Declarations

Ethics approval and consent to participate

The study was approved by Rwanda National Ethics Committee (Ethical approval 115/RNEC/2017). Dog owners were explained about this study and signed written consents before participating in the study.

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this article.

Competing interests

The authors declare that they have no competing interests

Funding

Part of this work has been funded by BHEARD, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013. The funder sponsored data collection that is buying reagents and materials and paying transport costs during the collection of faecal samples.

Authors' contributions

PN and PNN conceptualised the work. PN, PNN, FN designed the work. PN collected data and analysed faecal samples. PN and FN analysed and interpreted the data. PN drafted original manuscript. HG, PNN and FN revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank the management of the districts of Kigali city for authorising data collection. We are also grateful to dog owners for frank collaboration during data collection. Furthermore, the authors acknowledge the leadership of Rwanda Agriculture and Animal Resources Development Board for authorising use of the facilities of National Veterinary Laboratory.

Abbreviations

AOR: Adjusted Odds Ratio

EPG: Egg counts Per Gram

RAB: Rwanda Agriculture and Animal Resources Development Board

SPSS: Statistical Package for Social Sciences

BHEARD: Borlaug Higher Education for Agricultural Research and Development

RNEC: Rwanda National Ethics Committee

References

1. Wells DL. Domestic dogs and human health: an overview. *Br J Health Psychol.* 2007;12 :145–56.
2. Anderson WP, Reid CM, Jennings GL. Pet ownership and risk factors for cardiovascular disease. *Med J Aust.* 1992; 157:298–301.
3. Serpell J. Beneficial effects of pet ownership on some aspects of human health and behaviour. *J Roy Soc Med.* 1991; 84:717–20.
4. Bruce H, Grabka M. Health gains and budget savings due to pets: Australian and German longitudinal evidence. Conference: the 20th Anniversary of the German Socio-Economic Panel; Berlin;

2003. [Http://: www.vardhundskolan.se/Filer/headey-grabka 2003.pdf](http://www.vardhundskolan.se/Filer/headey-grabka%2003.pdf). Accessed 18 Aug 2017.
5. Wandeler AI, Macpherson CN, Meslin FX, editors. *Dogs, Zoonoses, and Public Health*. CABI Pub; 2000.
6. Soriano SV, Pierangeli NB, Roccia I, Bergagna HFJ, Lazzarini LE, Celescinco A, et al. A wide diversity of zoonotic intestinal parasites infects urban and rural dogs in Neuquen, Patagonia, Argentina. *Vet Parasitol*. 2010; 167:81–5.
7. Sharma R, Singh BB, Gill JPS, Jenkins E, Singh B. Canine parasitic zoonoses in India: status and issues. *Rev - Off Int Epizoot*. 2017; 36:817–30.
8. Traversa D. Pet roundworms and hookworms: a continuing need for global worming. *Parasit Vectors*. 2012; 5:91.
9. Ballweber LR. *Veterinary Parasitology (Practical Veterinarian)*, 1st edition. Butterworth-Heinemann Publication; 2001.
10. Despommier D. Toxocariasis: Clinical Aspects, Epidemiology, Medical Ecology, and Molecular Aspects. *Clin Microbiol Rev*. 2003; 16:265–72.
11. Shalaby HA, Abdel-Shafy S, Derbala AA. The role of dogs in transmission of *Ascaris lumbricoides* for humans. *Parasitol Res*. 2010; 106:1021–6.
12. Pullola T, Vierimaa J, Saari S, Virtala AM, Nikander S, Sukura A. Canine intestinal helminths in Finland: Prevalence, risk factors and endoparasite control practices. *Vet Parasitol*. 2006; 140:321–6.
13. Abere T, Bogale B, Melaku A. Gastrointestinal helminth parasites of pet and stray dogs as a potential risk for human health in Bahir Dar town, north-western Ethiopia. *Vet World*. 2013; 6:388–92.
14. Ilić T, Kulišić Z, Antić N, Radisavljević K, Dimitrijević S. Prevalence of zoonotic intestinal helminths in pet dogs and cats in the Belgrade area. *J Appl Anim Res*. 2017; 45:204-208.
15. Barutzki D, Schaper R. Results of parasitological examinations of faecal samples from cats and dogs in Germany between 2003 and 2010. *Parasitology research*. 2011; 109:45–60.
16. Neves D, Lobo L, Simões PB, Cardoso L. Frequency of intestinal parasites in pet dogs from an urban area (Greater Oporto, northern Portugal). *Vet Parasitol*. 2014; 200:295–8.
17. Robertson ID, Irwin PJ, Lymbery AJ, Thompson RCA. The role of companion animals in the emergence of parasitic zoonoses. *Int J Parasitol*. 2000; 30:1369–77.
18. Kołłątaj W, Milczak A, Kołłątaj B, Karwat ID, Sygit M, Sygit K. Risk factors for the spread of parasitic zoonoses among dog owners and their families in rural areas. *Ann Agric Environ Med*. 2012; 19:79–84.
19. Weng J, Wu H, Wang Z. Risk factors for early postoperative small bowel obstruction after anterior resection for rectal cancer: methodological issues. *World journal of surgery*. 2018; 42:1907–1907.
20. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Source code for biology and medicine. Source code for biology and medicine. 2008; 3:17.
21. Dhimal M, Aryal KK, Dhimal ML, Gautam I, Singh SP, Bhusal CL, et al. Knowledge, attitude and practice regarding dengue fever among the healthy population of highland and lowland communities in central Nepal. *PLoS One*. 2014;9: e102028.

22. Idika IK, Onuorah EC, Obi CF, Umeakuana PU, Nwosu CO, Onah DN. et al. Prevalence of gastrointestinal helminth infections of dog in Enugu State, South Eastern Nigeria. *Parasite Epidemiol Control*. 2017; 2:97–104.
23. Davoust B, Normand T, Bourry O, Dang H, Leroy E, Bourdoiseau G. Epidemiological survey on gastrointestinal and blood-borne helminths of dogs in north-east Gabon. *Onderstepoort Journal of Veterinary Research*. 2008; 75:359-364.
24. Ayinmode AB, Obebe OO, Olayemi E. Prevalence of potentially zoonotic gastrointestinal parasites in canine faeces in Ibadan, Nigeria. *Ghana Medical Journal*. 2016; 50:201-6.
25. Schandevyl P, Mbundu T, Sumbu W. Prevalence of intestinal parasites in dogs in Kinshasa, Zaire. *Ann de la Société belge de Médecine tropicale*. 1987; 67:369-74.
26. Bowman DD, Montgomery SP, Zajac AM, Eberhard ML, Kazacos KR. Hookworms of dogs and cats as agents of cutaneous larva migrans. *Trends in parasitology*. 2010; 26:162-7.
27. Dickson D Despommier, Daniel O Griffin, Robert W Gwadz, Peter J Hotez, Charles A Knirsch. *Parasitic diseases*. 7th edition. New York: Parasites Without Borders, Inc. NY; 2019.
28. Oliveira-Arbex AP, David EB, Oliveira-Sequeira TC, Katagiri S, Coradi ST, Guimarães S. Molecular identification of *Ancylostoma* species from dogs and an assessment of zoonotic risk in low-income households, São Paulo State, Brazil. *Journal of helminthology*. 2017;14-19.
29. Ivan E, Crowther NJ, Mutimura E, Osuwat LO, Janssen S, Grobusch MP. Helminthic infections rates and malaria in HIV-infected pregnant women on anti-retroviral therapy in Rwanda. *PLoS neglected tropical diseases*. 2013;7.
30. Ruberanziza E, Mupfasoni D, Karibushi B, Kabera M, Karema C, Nyatanyi T, et al. A recent update of Schistomiasis mansoni endemicity around Lake Rweru. *Rwanda Medical Journal*. 2010;68.
31. Sowemimo OA, Lee YL, Asaolu SO, Chuang TW, Akinwale OP, Badejoko BO. et al. Seroepidemiological study and associated risk factors of *Toxocara canis* infection among preschool children in Osun State, Nigeria. *Acta tropica*. 2017; 173:85-9.
32. Kyei G, Ayi I, Boampong JN, Turkson PK. Sero-epidemiology of *Toxocara canis* infection in children attending four selected health facilities in the central region of Ghana. *Ghana medical journal*. 2015;77–83:77–83.
33. Awadallah MAI, Salem LMA. Zoonotic enteric parasites transmitted from dogs in Egypt with special concern to *Toxocara canis* infection, *Vet World*. 2015; 8:946–57.
34. Irala JD, Fernandez-Crehuet Navajas R, & Serrano del Castillo A. Abnormally wide confidence intervals in logistic regression: interpretation of statistical program results. *Revista Panamericana de Salud Pública*. 1997; 2:268–71.
35. National Institute of Statistics of Rwanda. *Statistical Yearbook 2014*. Republic of Rwanda; 2014.
36. The New Times. Three thousand dogs culled in Rwanda in 2016. 2017.
[Http://www.newtimes.co.rw/section/read/222517/](http://www.newtimes.co.rw/section/read/222517/). Accessed 25 Feb 2020.

37. Ntampaka P. Assessment of the effectiveness of anti-rabies vaccination of dogs in Kigali city, Rwanda. MSc dissertation, University of Nairobi; 2018.
38. National Institute of Statistics of Rwanda (NISR), Ministry of Health (MOH), Rwanda, and ICF. Rwanda Demographic and Health Survey 2014-15. Rockville, Maryland, USA: NISR, MOH, and ICF International; 2016.
39. Bartlett EJ, Kotrlik WJ, Higgins CC. Organizational Research: determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*. 2001;19.
40. Ali A. Al-Subaihi. Sample size determination Influencing factors and calculation strategies for survey research. *Saudi Med J*. 2003; 24 (4):323–30.
41. Cochran W.G. Sampling techniques. 3rd ed. New York: John Wiley & Sons; 1977.
42. Hansen J, Perry BD. The epidemiology, diagnosis, and control of helminth parasites of ruminants. A handbook. 2nd edition. Nairobi, Kenya: The international Laboratory for Research on Animal Diseases; 1994.
43. García Segura F, Aranda Aburto MS, Espino Barros Oscar Agustín, Hernández Hernández J, Camacho Ronquillo JC, Portillo Monroy A. Prevalence study of external and internal parasites in the municipality of rabbits in Libres, Puebla, Mexico. Mexico: Autonomous Mexico State University; 2014.
44. Baron S. Medical Microbiology (Cestodes). 4th edition. University of Texas Medical Branch at Galveston.; 1996.
45. Soulsby E.J.L. A textbook of Helminths, arthropods and protozoa of domesticated animals. 7th edition. 1982.
46. Rodriguez-Vivas RI, Gutierrez-Ruiz E, Bolio-González ME, Ruiz-Pina H, Ortega-Pacheco A, Reyes-Novelo E, et al. An epidemiological study of intestinal parasites of dogs from Yucatan, Mexico, and their risk to public health. *Vector-Borne and Zoonotic Diseases*. 2011; 11:1141–4.
47. Peng CYJ, So TSH. Logistic Regression Analysis and Reporting: A Primer. *Understanding Statistics*. 2002; 1:31-70.

Additional Files

Additional file 1: questionnaire for data collection

Additional file 2: Completed STROBE check list for cross-sectional studies

Figures

Figure 1

Parasitic egg load in dogs suffering from ancylostomosis and toxocarosis in Kigali city. Around 38.7% and 3.2% of the dogs infected with *Ancylostoma* spp and *Toxocara canis* had high egg load (≥ 500 EPG), respectively. In addition, 35.5% and 22.6% of those infected with *Ancylostoma* spp had moderate egg load (150-500 EPG) and low egg load (50-100 EPG), respectively. Data on egg counts per gram of faeces were not available for dogs infected with cestodes. In these dogs, the worms or their segments were detected macroscopically.

Figure 1

Parasitic egg load in dogs suffering from ancylostomosis and toxocarosis in Kigali city. Around 38.7% and 3.2% of the dogs infected with *Ancylostoma* spp and *Toxocara canis* had high egg load (≥ 500 EPG), respectively. In addition, 35.5% and 22.6% of those infected with *Ancylostoma* spp had moderate egg load (150-500 EPG) and low egg load (50-100 EPG), respectively. Data on egg counts per gram of faeces

were not available for dogs infected with cestodes. In these dogs, the worms or their segments were detected macroscopically.

Figure 2

Figure 2

Map of the study area with the nine selected study sectors. Fig.2 shows administrative districts (red boundaries) and sectors (gray boundaries) of Kigali City. The blue dots show location of households owning sampled dogs across the study sites. The locations are Kigali, Nyamirambo and Mageragere sectors of Nyarugenge district; Kicukiro, Niboye and Gatenga sectors of Kicukiro district as well as Gisozi, Kimironko and Kacyiru sectors of Gasabo district. Data on the location of each study dog was collected using GPS and allowed generating the map using ArcGis10.2 software.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1.docx](#)
- [Additionalfile1.docx](#)
- [AdditionalFile2.pdf](#)
- [AdditionalFile2.pdf](#)