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GASTROINTESTINAL PARASITES OF HOUSEHOLD DOGS AND CATS: EPIDEMIOLOGY AND COMMUNITY KNOWLEDGE, ATTITUDE AND PRACTICES ABOUT THE PARASITES IN SELECTED CENTRAL PARTS OF ETHIOPIA

PhD Dissertation

By

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Department of Microbiology, Parasitology and Poultry Health

PhD Program in Veterinary Parasitology

June, 2025

Bishoftu, Ethiopia

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A Dissertation Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Veterinary Parasitology

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ADDIS ABABA UNIVERSITY
COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE
DEPARTMENT OF MICROBIOLOGY, PARASITOLOGY AND POULTRY HEALTH

Gastrointestinal Parasites of Household Dogs and Cats: Epidemiology and Community Knowledge, Attitude and Practices About the Parasites in Selected Central Parts of Ethiopia

PhD Dissertation

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ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

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As members of the examining board of the PhD open defence, we certify that we have read and evaluated the dissertation prepared by Kibruyesfa Bayou Tegegn titled: "*Gastrointestinal Parasites of Household Dogs and Cats: Epidemiology and Community Knowledge, Attitude and Practices About the Parasites in Selected Central Parts of Ethiopia*" and recommend that to be accepted as fulfilling the dissertation requirements for the Degree of Doctor of Philosophy in Veterinary Parasitology.

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STATEMENT OF AUTHOR

I declare that this dissertation is my authentic and real work and that all source materials used for this PhD thesis have been properly acknowledged. This thesis has been duly submitted in fulfilment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the library. I sincerely declare that this PhD thesis is not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of department or the Dean of the College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

I was born on April 12, 1983, in Addis Ababa. I attended my elementary and secondary education in Addis Ababa at Kechene Debreselam Elementary Junior Secondary School and Yekatit 12 Senior Secondary School, respectively. I earned my Doctor of Veterinary Medicine (DVM) degree from Addis Ababa University, Faculty of Veterinary Medicine in 2007. Then, I was employed at Alage Agricultural TVET College in 2007 and served for seven years as an instructor of different Veterinary Medicine courses. For my professional development, I joined Addis Ababa University, College of Veterinary Medicine and Agriculture in 2014 to continue my MSc degree, and I received my MSc in Veterinary Pathology in 2015. Then, in search of better work experience, I joined Wollega University, School of Veterinary Medicine, in November 2015 and served as an Assistant Professor of Veterinary Pathology until September 2020. From September 2020 to date, I have served as an Associate Professor of Veterinary Pathology. During my professional career, I earned different certificates of trainings from different institutions, and I published 20 articles in international scientific journals. In December 2020, I re-joined Addis Ababa University, College of Veterinary Medicine and Agriculture to pursue my PhD program in Veterinary Parasitology, and I did my PhD research work on “Gastrointestinal Parasites of Dogs and Cats: Epidemiology and Community Knowledge, Attitude and Practices About the Parasites in Selected Central Parts of Ethiopia”.

DEDICATION

This dissertation is dedicated to my mother Meaza Menda, who passed away during my PhD study. May she rest in peace!

GASTROINTESTINAL PARASITES OF HOUSEHOLD DOGS AND CATS: EPIDEMIOLOGY AND COMMUNITY KNOWLEDGE, ATTITUDE AND PRACTICES ABOUT THE PARASITES IN SELECTED CENTRAL PARTS OF ETHIOPIA

Kibruyesfa Bayou Tegegn
PhD Dissertation
College of Veterinary Medicine and Agriculture, Addis Ababa University, 2025

ABSTRACT

Both dogs and cats are affected by diverse groups of gastrointestinal (GI) parasites and may also act as infection sources for other animals and humans. Despite fragmented reports, a wide area survey of the status of GI parasite infection in these animals and the community's knowledge, attitude and practices of the problem has never been conducted. Therefore, a cross-sectional study on GI parasites of dogs and cats was carried out from February, 2022 to April, 2023 in Dukem, Bishoftu, Addis Ababa and Sheno areas of central Ethiopia with the objectives to estimate the prevalence and assess the risk factors of these parasites. In addition, a community-based questionnaire survey was conducted on 272 dog and cat owners to assess their knowledge, attitude and practices (KAP) toward dog and cat GI parasites. A total of 914 (701 dog and 213 cat) faecal samples were collected and processed using centrifugal-floatation technique and McMaster technique to identify GI parasites and to quantify their burden. A post-mortem examination was conducted on 13 dogs to explore the GI tract for any adult parasites. Based on faecal examination, an overall prevalence of 53.1% (372/701) and 34.7% (74/213) GI parasites was recorded in dogs and cats, respectively. Dogs and cats were found to be infected with nematode (28.2% and 14.6%), cestode (8.4% and 12.7%), and protozoan (5.6% for each: dog and cat). Among these, 42.2% and 32.9% were single infections, while 10.8% and 1.9% were mixed infections in dogs and cats, respectively. In dogs, *Ancylostoma* spp., *Toxocara canis*, *Dipylidium caninum*, *Giardia* spp. and *Taenia/Echinococcus* spp. were more frequent parasites with the prevalence of 16%, 9.8%, 5%, 3.9% and 3.1%, respectively. Whereas *Toxocara cati*, *Dipylidium caninum*, *Taenia* spp., *Giardia* spp. and *Physaloptera* spp. were more frequent parasites in cats with the prevalence of 9.4%, 8.9%, 3.8%, 2.8% and 2.8%, respectively. A statistically significant difference ($P<0.05$) was observed in the prevalence of GI parasites of dogs of different origin, sex, age, feeding conditions, housing conditions and agro-ecology, and of cats of different sex, age, feeding conditions. Thus, higher prevalence of GI parasites was observed in female dogs and cats (73.8%, OR=0.4 and 49.1%, OR=2.3, respectively), adult dogs (55.3%, OR=0.4), young cats (70%, OR=4.7), in dogs and cats that were commonly fed uncooked food (57.9%, OR=2.7 and 40.5%, OR=3.6, respectively) and in dogs and cats which were housed free outdoor (60.9%, OR=2.4 and 35%, respectively). Similarly, a higher prevalence of GI parasites of dogs and cats was observed in dogs from highland areas (62.1%, OR=1.8) and in cats from midland areas (36.1%, OR=1.3). From the thirteen dogs that were examined using the post-mortem technique, one dog was found to have an intestine packed with *Toxocara canis*. From the 272 respondents in the KAP study, the majority, 159 (58.5%) of the respondents were found to keep their pets free outdoor, and 133 (48.9%) of them fed their pets raw offal/meat/milk. The questionnaire survey disclosed that dog and cat owners had an overall good knowledge (score=54.6% and 63.9%, respectively), positive attitude (score=82.1% and 84.1%, respectively), and poor practices (score=46% and 37.6%, respectively) towards GI parasites of dogs and cats. In conclusion, the current study indicated a high prevalence of GI parasites in dogs and cats within the considered areas. Dog and cat owners had good knowledge, positive attitude, and poor practices regarding GI parasites of dogs and cats. Therefore, to implement effective control and prevention methods, One Health approach is essential and an in-depth epidemiological and molecular investigation is needed to identify GI parasites of dogs and cats considering wide study areas with different agro-ecologies to understand their economic and zoonotic impacts. Dog and cat owners should perform good practices and stay current with the most recent knowledge and practices to prevent and control dog and cat GI parasites.

Keywords: Attitude; Cats; Central Ethiopia; Dogs; Gastrointestinal parasites; Knowledge; Practice; Prevalence; Risk factors.

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Last but not least, I owe a debt of gratitude to my family for bearing with me throughout my absence and for their love and support during my study years.

LIST OF PUBLICATIONS

From this dissertation, three articles were published, and the articles are found at the end of this document.

Published articles:

1. Kibruyesa, B., Getachew, T., & Bersissa, K. (2024). Gastrointestinal parasites of owned cats in three districts of Central Ethiopia: Prevalence and risk factors. *Veterinary Parasitology: Regional Studies and Reports*, *52*, 101053. https://doi.org/10.1016/j.vprsr.2024.101053

2. Kibruyesa, B., Getachew, T., & Bersissa, K. (2025). Epidemiology of gastrointestinal parasites of dogs in four districts of Central Ethiopia: Prevalence and risk factors. *PLOS ONE*, *20*(1), e0316539. https://doi.org/10.1371/journal.pone.0316539

3. Kibruyesa, B., Getachew, T., & Bersissa, K. (2025). Knowledge, attitude and practices of dog and cat owners toward pet gastrointestinal parasites and associated zoonosis in selected districts of Central Ethiopia. *Veterinary Research Notes*, *5*(3), 21–32. https://doi.org/10.5455/vrn.2025.e53

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LIST OF ABBREVIATIONS

CDC	Centre for Disease Control and Prevention
CSA	Central Statistical Agency
DNA	Deoxyribonucleic acid
ELISA	Enzyme-linked immunosorbent assay
ESCCAP	European Scientific Counsel Companion Animal Parasites
EPG	Eggs per Gram of Faeces
GI	Gastrointestinal
KAP	Knowledge, attitude and practices
PCR	Polymerase Chain Reaction
PPP	Prepatent period
rpm	Revolution per minute
S.G	Specific gravity
TES	*Toxocara* excretory/secretory
TroCCAP	The Tropical Council for Companion Animal Parasites
WHO	World Health Organization

LIST OF APPENDICES

1. INTRODUCTION

Dogs and cats are the most common pets worldwide (Menchetti *et al*., 2024). They are frequently regarded as people's closest and most devoted pals. The emotional growth, socialization, and physical health of their owners can all be significantly improved by this human-animal link (McConnell *et al*., 2011). Since these animals are often considered family members by their owners, human beings are responsible for giving attention to the health and well-being of dogs and cats under their custody (Bashir *et al*., 2024). It's also critical to stress that, if not properly managed, both owned and stray dogs may play deleterious roles as human hosts for zoonotic illnesses (Robertson *et al*., 2000). Humans are exposed to zoonotic agents due to increased contact between domestic animals and people brought on by the growing number of companion animals (Mahendra and Dinaol, 2023).

Dogs play a significant role in both urban and rural Ethiopian families, usually acting as house guards (Hailu *et al*., 2019) and as companion animals. Similarly, cats are also kept either as companion animals or to chase rodents away from homes. There is a lack of reliable information on Ethiopia's dog and cat populations (Endrias *et al*., 2020). However, an estimate shows that the country has over 5 million dogs (Yobsan *et al*., 2022). Most dogs in Ethiopia are stray dogs, roaming around streets, homesteads, abattoirs, butcher shops and marketplaces. Such dogs have been found to have the highest parasite burdens (Teshager *et al*., 2023).

Both uncontrolled and poorly managed dog and cat populations are known to harbour and spread several zoonotic illnesses, such as rabies, throughout the world (Deressa *et al*., 2010), toxoplasmosis (Gebremedhin and Tadesse, 2015), leishmaniasis (Lemma *et al*., 2009), echinococcosis (Kebede *et al*., 2009) and toxocariasis (Deplazes *et al*., 2011). More than sixty zoonotic parasites have definitive hosts or reservoirs in carnivores (Kohansal *et al*., 2017). Gastrointestinal parasites are the dominant agents infecting domestic dogs and cats (Silva *et al*., 2020) with mild to severe consequences and often with zoonotic potential.

The most common enteric parasites of dogs are *Toxocara canis, Ancylostoma caninum, Taenia hydatigena*, *Echinococcus* spp., *Dipylidium caninum*, *Trichuris vulpis*, *Giardia* spp., *Cryptosporidium* spp. and *Cystoisospora canis* (Palmer *et al*., 2008). In different countries, the prevalence of endoparasites in dogs ranges from 5% to 70% (Alho *et al*., 2018; La Torre *et al*., 2018; Sarvi *et al*., 2018). These studies showed that *Trichuris* spp*.*, *Toxocara* spp*.*, *Ancylostoma* spp. and *Cystoisospora* spp. were among the most prevalent canine intestinal parasites (Urgel *et al*., 2019). Similarly, in addition to being identified as significant public health issues in several regions of the world, gastrointestinal parasites are a major cause of illnesses in cats in the tropics (Buijs, 1993). Cats can have a vast range of helminth parasites with different species (Rabbani *et al.*, 2020). The common ones include helminths such as *Toxocara cati*, *Toxascaris leonina*, *Ancylostoma* sp., cestodes viz. *Diphyllobothrium* sp., *Dipylidium caninum* and protozoan such as *Isospora felis*, *Isospora rivolta*, *Giardia* and *Eimeria* spp.

Dogs and cats are important reservoir hosts for gastrointestinal zoonotic parasites, such as nematodes, cestodes, and protozoa (Gustavo *et al*., 2007). Several gastrointestinal parasites of carnivores particularly *Toxocara*, *Ancylostoma*, *Trichuris*, *Strongyloides*, *Gnathostoma*, *Dipylidium*, *Taenia*, *Spirometra*, *Hymenolepis*, *Giardia*, *Entamoeba*, *Blastocystis* and *Toxoplasma* are widespread parasites of dogs and cats that have the potential to spread disease globally. This fact highlights the necessity of a One Health strategy to manage and control these parasites more effectively (Dantas-Torres *et al*., 2012; Satyal *et al*., 2013).

1.1. Statement of the problem

Gastrointestinal (GI) parasites have been identified as significant public health issues in several regions of the world and are a major source of infections in dogs and cats in the tropics (Buijs, 1993). High prevalence and heavy infections with GI parasites are more commonly reported in dogs in developing countries (Perera *et al*., 2013). The estimated pooled prevalence of dog and cat gastrointestinal helminths in Sub-saharan Africa and East Africa was 71% and 81%, respectively (Nozyechi, 2018).

Many households in Ethiopia own one or more dogs and cats (Endrias *et al*., 2020). However, a large number of unconfined dogs and cats with a high zoonotic parasite prevalence, as well as a lack of public awareness regarding the welfare, regular diagnosis and treatment of these animals, and public health risks of their diseases make this a very concerning issue for the nation (Oliveira-Sequeira *et al*., 2002; Palmer *et al*., 2008; Getachew *et al*., 2015).

In Ethiopia limited studies have shown that the prevalence of intestinal parasites in privately owned dogs (Abere *et al*., 2013; Getahun and Addis, 2012; Gebreselasie *et al*., 2013) with a range of 52.9%-94.6% prevalence of gastrointestinal helminth parasites (Endrias *et al*., 2010; Octavius *et al*., 2019; Mitiku *et al*., 2020; Teshager *et al*., 2023). And only a few reports exist regarding gastrointestinal parasites of privately owned cats from Ethiopia (Nateneal *et al*., 2015). In most cases, the data of those reports on dog and cat gastrointestinal parasites were gathered from a single town or district that dealt with either on dog or cat gastrointestinal parasites in their respective study areas.

Specifically, up-to-date reports from Central Ethiopia (particularly in Dukem, Bishoftu, Sheno and Addis Ababa) on the prevalence of GI parasites of dogs and cats are scanty. Similarly, not much is known about the awareness and practice of the dog and cat-owning community in central Ethiopia regarding regular dog and cat deworming, prevention of environmental contamination and risks of zoonosis and protective measures against parasitic infection of dogs and cats (Merga and Sibhat, 2015). Understanding the epidemiology of the diseases as well as community knowledge, attitudes, and practices regarding the disease's transmission channels and other features is essential to develop an effective control program against diseases of high public health relevance (Zerfu *et al*., 2024).

Thus, the following research questions and objectives were formulated to study gastrointestinal parasites of dogs and cats and to assess the community awareness on the parasites in selected study areas (Dukem, Bishoftu, Sheno and Addis Ababa) in Central Ethiopia. In this study, stray dogs were not included because of the fact that these animals do not have a specific address or responsible owners to assess their knowledge, attitude and practices on gastrointestinal parasites of dogs and cats.

1.2. Research questions

This study has systematically addressed the following main research questions:

- What is the prevalence of gastrointestinal parasites of dogs and cats in selected districts of central Ethiopia?
- What are the risk factors for the occurrence of gastrointestinal parasites of dogs and cats in selected districts of central Ethiopia?
- What is the level of knowledge, attitude, and practices of the community about gastrointestinal parasites of dogs and cats in selected districts of central Ethiopia?

1.3. Objectives

1.3.1. General objective

The general objective of the study was to investigate gastrointestinal parasitism of dogs and cats and owners' understanding and practices about the parasites in selected districts of central Ethiopia.

1.3.2. Specific objectives

- ➢ To estimate the prevalence and identify risk factors of gastrointestinal parasites of dogs in selected districts of central Ethiopia.
- ➢ To estimate the prevalence and identify risk factors of gastrointestinal parasites of cats in selected districts of central Ethiopia.
- ➢ To assess the level of knowledge, attitude and practices of the community on gastrointestinal parasites of dogs and cats in selected districts of central Ethiopia.

2. LITERATURE REVIEW

2.1. Gastrointestinal parasites of dog and cat and their significance

Many people believe that dogs and cats are people's closest and most devoted pals (McGlade *et al*., 2003). There have been several reports of intestinal parasites in household cats and dogs. *Ancylostoma* species, *Toxocara* species, *Trichuris* species, *Dipylidium caninum*, *Strongyloides stercoralis*, *Giardia* species, *Cystoisospora* species, and *Cryptosporidium* species are among the helminths and protozoa that are commonly identified in these animals (Arruda *et al*., 2021; Kamani *et al*., 2021). The parasite type, parasite load, animal health, and the existence of co-infections, including in other systems (respiratory, etc.), all influence whether or not animals exhibit clinical symptoms as a result of these parasites (Taylor *et al*., 2016). Thus, enteric infections may be asymptomatic or evolve into moderate-to-severe gastrointestinal problems, anorexia, and developmental delays, which can result in patient mortality (Spinosa *et al*., 2022).

Dogs and cats can get gastrointestinal parasite infections in single or in combination. Single infections and co-infections were more common in dogs (20.5% to 62.2% and 16.1% to 37.4%, respectively) than in cats (46.2% to 90.9% and 3.3% to 41.4%) (Takeuchi-Storm *et al*., 2015; Nagamori *et al*., 2018; Kamani *et al*., 2021).

Humans and domestic animals, especially dogs and cats, are now much closer. Although pets help their guardians, their close proximity to one another promotes the transmission of zoonoses, which has been increasingly studied in the past ten years (Kajero *et al*., 2022). For many years, the primary culprits of cutaneous and visceral larva migrans classic instances of zoonotic infections spread by dogs and cats have been identified as *Ancylostoma* spp. and *Toxocara* spp. (Del Giudice *et al*., 2019; Özbakış and Doğanay, 2020). However, additional infections, including *Echinococcus* spp. (Kesteren *et al*., 2013) and *Strongyloides* spp. (Sanpool *et al*., 2019), which are significant parasites of public health significance, should also receive attention. It's crucial to remember that some protozoans, such as *Cryptosporidium* and *Giardia,* are frequently reported in domestic dogs and cats (Ryan and Cacciò, 2013). For instance, the *Giardia* species has been responsible for more than 280 million human cases of diarrhoea every year (Horlock-Roberts *et al*., 2017).

2.2. Nematodes

In many regions of the world, intestinal nematodes are recognized as agents that may have an impact on both the general welfare of society and the health of animals. An important challenge to both public and animal health is intestinal nematode infection (Tadege *et al*., 2022). Both cats and dogs can have a variety of nematodes. The small and large intestines are home to a variety of nematode species. Roundworms of the genus *Toxocara* (*T. canis, T. cati*) and *Toxascaris* (i.e., *T. leonina*) and hookworms of the genus *Ancylostoma* (*A. caninum, A. braziliense, A. tubaeforme*) or *Uncinaria* (*U. stenocephala*) and *Strongyloides* are important species that inhabit the small intestine. Nematodes belonging to the genus *Trichuris* (*T. vulpis*) are parasites of the large intestine (Christian, 2009). From the stomach nematodes, the genus *Physaloptera* is the main one (Darabi *et al*., 2021; Adhikari *et al*., 2023).

2.2.1. Epidemiology

From the gastrointestinal nematodes, the most dependable intestinal parasites in dogs and cats are most likely hookworms. They can infect animals of any age, but they pose a serious risk to the very young and may even kill the fully grown hookworm-resistant host. The two genera of hookworm have a geographic distribution almost entirely attributable to climate, with some evidence of host specificity. *Uncinaria stenocephala* is a parasite of the dog, fox, wolf, and lynx; it occurs only rarely, and probably accidentally, in the domestic cat. The genus *Ancylostoma* (*A.*) is found in tropical and subtropical regions and in the warmer parts of the temperate zone. Of the five species of *Ancylostoma*, *A. caninum* is the most widely distributed. It parasitizes canids (dogs, foxes, and coyotes). *Ancylostoma tubaeforme*, a parasite of the house cat. *Ancylostoma braziliense*, a parasite of felids and canids, occurs in the house cat, leopard, and cheetah, as well as in the dog, fox, and wolf in the warmer parts of the world (Ulrich,1987). Warm, wet, sandy soil that is protected from direct sunshine is ideal for hookworm larvae development. Because of this, the majority of dog and cat cases of hookworm disease happen in the late spring, summer, and early fall (Bowman *et al*., 2003).

Although hookworm infection is observed in dogs of all ages, pups and juveniles are more likely to exhibit clinical signs of disease (Reinemeyer, 2016). Ancylostomiasis has gained major importance in veterinary as well as in public health research. The prevalence of *Ancylostoma* spp. in cats in several countries has proven the importance of this disease (Hu *et* *al*., 2015). *Ancylostoma* species are prevalent in Sub-Saharan Africa (including Ethiopia), the Americas, Europe and Asia (Table 1).

Table 1. Reports on *Ancylostoma* species of dog and cat from various regions of the world.

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Northeastern India	*A. caninum* Mixed infection with *A. caninum* and *A. braziliense*	24 38	- -	PCR-RFLP	Traub *et al*. (2004)
Hawassa city, Ethiopia	*A. caninum*	54.5	-	Mc master egg counting ch amber and sedimentation te chniques	Dejene *et al*. (2013)
Sokoto, Nigeria	*A. tubaeforme*	-	16.7	Sedimentation using formol-ether and floatation techniques	Raji *et al*. (2013)
Al-Diwaniya province, Iraq	*Ancylostoma* spp.	-	23.3	Faecal floatation and sedimentation techniques	Hussam (2015)
Mekelle town, Ethiopia	*Ancylostoma* spp.	16.2	-	Faecal floatation	Getachew *et al*. (2015)
Haramaya town, Ethiopia	*Ancylostoma* spp.	70.5	37.5	Faecal floatation	Nateneal *et al*. (2015)
Rio de Janeiro, Brazil	*Ancylostoma* spp.	-	93.3	Centrifugal sedimentation and flotation techniques	Pâmela *et al*. (2017)
Chagni town, Ethiopia	*Ancylostoma* spp.	92.6	-	Kato-Katz methodology	Nigatu (2019)
Jimma town, Ethiopia	*A. caninum*	58.8	-	Faecal floatation	Hailu *et al*. (2019)
Hosanna town, Ethiopia	*Ancylostoma* spp.	49	-	Sedimentation and floatation techniques	Yimer *et al*. (2019)
USA/Georgia	*Ancylostoma* spp.	-	11.7	Centrifugation sugar flotation	Hoggard *et al*. (2019)
Bishoftu town, Ethiopia	*Ancylostoma* spp.	29.4	-	Faecal floatation	Mitiku *et al*. (2020)
Italy	*Ancylostoma* spp.	-	9.9	Sedimentation and floatation techniques	Genchi *et al*. (2021)

Table 1 (Continued)

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Kigali city, Rwanda	*Ancylostoma* spp.	32.3	-	Flotation method	Pie *et al*. (2021)
Morocco	*Ancylostoma* spp.	31.9	-	Centrifugal flotation and simple flotation techniques	Houda *et al.* (2022)
Dhaka, Bangladesh	*Ancylostoma* spp.	-	9.3	Centrifugal flotation technique	Mandira *et al*. (2022)
Hawassa town, Ethiopia	*Ancylostoma* spp.	15.4	-	Flotation technique	Teshager *et al*. (2023)

PCR: polymerase chain reaction; RFLP: Restriction Fragment Length Polymorphism.

Because of their zoonotic relevance, *Toxocara canis* and *Toxocara cati* are cosmopolitan roundworms that affect both cats and dogs and have significant public health implications (Ma *et al*., 2018). Both definitive and paratenic hosts, including humans, can become infected due to the extensive environmental contamination caused by *Toxocara* (*T*.) eggs found in the faeces of definitive hosts (ESCCAP, 2004). Puppies, young dogs under six months of age, and kittens have the largest worm burdens and prevalence of patent *Toxocara* spp. infections. To develop the best control methods, more research on the dynamics of infection in older dogs is required. The epidemiological significance of adult dogs as an infection reservoir should not be undervalued because age-independent estimations of the intensity of infection have been achieved for adult dogs that do not exhibit any clinical symptoms (Reperant *et al*., 2009).

Unfortunately, most domestic and peri-domestic dogs and cats, especially young ones, are infected with *T. canis* and *T. cati*. Adult worms may be present in even those offered for sale by reputable kennels and pet stores. This is because *Toxocara* juveniles are transferred from the diseased mother to puppies and kittens. As a result, it has been determined that having a litter of puppies at home poses a serious risk (Marmor *et al*., 1987). The most prevalent gastrointestinal helminths in the world for household dogs and cats are likely *T. canis* and *T. cati*, roundworms of dogs and cats (Overgaauw, 1997). In Western Europe, reported *T. canis* and *T. cati* infection rates range from 3.5% to 34% for *T. canis* in dogs from different epidemiological environments (pet, shelter, stray, and rural dogs) and from 8% to 76% for *T.*

cati in cats (Martínez-Carrasco *et al*., 2007; Lee *et al*., 2010). In Ethiopia, *T. canis* infections were reported in Wondo Genet, Bahir Dar and Chagni, as indicated in table 2.

Table 2. Reports on *Toxocara* species of dog and cat from various regions of the world.

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Porto Alegre, Brazil	*Toxocara* spp.	15.3	28.8	Floatation technique	Gustavo *et al*. (2007)
Bahir Dar town, Ethiopia	*T. canis*	26.6	-	Sedimentation and flotation techniques	Zelalem and Mekonnen (2012)
Hawassa town, Ethiopia	*T. canis*	32	-	Sedimentation technique	Dejene *et al.* (2013)
Malaysia	*Toxocara* spp.	34.4	48	Standard direct smear and formalin ethyl acetate concentration techniques	Romano *et al.* (2014)
Northern Italy	*T. canis*	4.5	-	Centrifugation-flotation technique	Sergio *et al*. (2014)
	T. cati	-	5.6		
Nakhon Nayok, Thailand	*T. canis* *T. cati*	6.6	- 9.7	Formalin-ether concentration technique	Wichit *et al.* (2014)
Mekelle, Ethiopia	*T. canis*	23.3	-	Floatation technique	Getachew *et al*. (2015)
Haramaya town, Eastern Ethiopia	*Toxocara* spp.	30.3	32.5	Floatation technique	Nateneal *et al.* (2015)
Wondo Genet, Ethiopia	*T. canis*	39.8	-	Kato-Katz methodology	Octavius *et al*. (2019)
Chagni town, Ethiopia	*T. canis*	88	-	Kato-Katz methodology	Nigatu (2019)
Jimma town, Ethiopia	*T. canis*	25.8	-	Floatation technique	Hailu *et al.* (2019)
Bishoftu town, Ethiopia	*T. canis*	19.8	-	Floatation technique	Mitiku *et al.* (2020)

Table 2 (Continued)

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Plateau State, Nigeria	*T. canis*	30.9	-	Floatation and sedimentation techniques	Karaye *et al*. (2021)
Rio de Janeiro, Brazil	*T. canis* *T. cati*	1 -	- 1.9	Sedimentation and centrifugal-flotation techniques	Igor Falco *et al*. (2021)
Bangkok, Thailand	*T. canis* *T. cati*	5.4	- 0.6	Sedimentation and centrifugal-flotation techniques	Phoosangwalthong *et al*. (2022)
France	*T. canis*	8.5	-	Sedimentation and centrifugal-flotation techniques	Gilles *et al*. (2022)

A nematode belonging to the Rhabditida order, *Strongyloides stercoralis* has a worldwide range and an intricate life cycle. This tiny, thread-like worm infects humans, dogs, cats, and primates. Although it can also be found in temperate regions, it is most frequently found in tropical and subtropical regions (Thamsborg *et al*., 2017). It infects humans, dogs, cats, and primates and is regarded as a multi-host parasite (Barnes *et al.*, 2017). Most common of canine *Strongyloides* (*S.*) *stercoralis* infections occur in puppies and young dogs younger than one year, as well as puppies housed in unsanitary breeding kennels during hot and muggy seasons (Eydal and Skírnisson, 2016). In addition to autoinfection, *Strongyloides stercoralis* can infect the host through transmamary, percutaneous, or oral transmission (Dillard *et al*., 2007). Cats have been experimentally infected with *S. stercoralis*. Though the species is unknown, *Strongyloides* is seen in cats in both Europe and Africa; it may be *S. stercoralis* (Abu-Madi *et al*., 2007).

The picture of prevalence around the world is as varied as the kinds and quantities of studies conducted. According to available data, between 10% and 40% of people in several tropical and subtropical nations are infected with *S. stercoralis* (Schar *et al*., 2013). *Strongyloides stercoralis* prevalence ranges from 0 to over 50% in dogs, with most studies indicating 0.2 to 5%, with younger dogs more likely to be infected (Paulos *et al*., 2012; Riggio *et al*., 2013). The prevalence of *Strongyloides* in cats ranges from 0 to 4% (Mohd Zain *et al*., 2013; Takeuchi-Storm *et al*., 2015). *Strongyloides* infections were less common in cats than in dogs in studies comparing parasites in dogs and cats (Stig *et al*., 2017). Prevalences among private home dogs ranged from 0.6% to 1.4% in Japan but were higher in Cambodia (14.9%) (Itoh *et al*., 2009; Schar *et al*., 2014). While more recent data showed prevalences of 3.9% and 1.6%, higher prevalences (5-60%) were discovered on the African continent (Table 3), for example, in Nigerian canines (Adekunle *et al*., 2016; Kamani *et al*., 2021).

Table 3. Reports on prevalence rates of *Strongyloides* of dog and cat from various regions of the world.

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Porto Alegre, Brazil	*Strongloid* spp.	0.4	1.7	Flotation technique	Gustavo *et al*. (2007)
Ambo town, Ethiopia	*S. stercoralis*	14.3	-	Sedimentation and flotation techniques	Endrias *et al*. (2010)
Hawassa town, Ethiopia	*S. stercoralis*	57.5	-	Sedimentation and flotation techniques	Dagmawi *et al*. (2012)
Bahir Dar town, Ethiopia	*S. stercoralis*	8.6	-	Sedimentation and flotation techniques	Zelalem and Mekonnen (2012)
Hawassa city, Ethiopia	*S. stercoralis*	35	-	Sedimentation technique	Dejene *et al*. (2013)
Nakhon Nayok, Thailand	*Strongloid* spp.	-	0.7	Formalin-ether concentration	Wichit *et al*. (2014)
Northern Italy	*S. stercoralis*	1.9	-	Centrifugal flotation technique	Sergio *et al*. (2014)
Adama Town, Central Ethiopia	*S. stercoralis*	5.5	-	Sedimentation and flotation techniques	Tolera and Berhanu (2015)
Haramaya town, Eastern Ethiopia	*Strongloid* spp.	15.1	-	Centrifugal flotation technique	Nateneal *et al*. (2015)
Ibadan, Nigeria	*Strongyloides* sp.	3.9	-	Flotation technique	Adekunle *et al*. (2016)
Thasala, Thailand	*S. stercoralis*	-	29.4	Modified formal-ether concentration and agar plate culture	Blego and Witthaya (2018)
Chagni town, Ethiopia	*S. stercoralis*	60.1	-	Kato-Katz methodology	Nigatu (2019)

Table 3 (Continued)

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Hosanna town, Ethiopia	*S. stercoralis*	2.6	-	Sedimentation and floatation techniques	Yimer *et al*. (2019)
Wondo Genet, Ethiopia	*S. stercoralis*	46.1	-	Kato-Katz methodology	Octavius *et al*. (2019)
Italy	*S. stercoralis*	-	2	Sedimentation and floatation techniques	Genchi *et al*. (2021)
Puebla City, Mexico	*Strongyloides* sp.	2	-	Flotation technique	Contreras-Flores *et al*. (2021)
Hawassa town, Ethiopia	*S. stercoralis*	24.2	-	Flotation technique	Teshager *et al*. (2023)

Spirurid nematodes in the genus *Physaloptera* (*P.*) are members of the family *Physalopteridae* within the order *Spirurida*. Only two species, *P. praeputialis* and *P. rara*, are frequently found in dogs and cats, even though many species have been found in a range of vertebrate hosts throughout the world (Jennifer *et al.*, 2021). These gastrointestinal parasites use a range of arthropod intermediate hosts, including flour beetles, cockroaches, and crickets, and are spread by an indirect life cycle (Naem and Asadi, 2013). Mammals, reptiles, and amphibians are among the paratenic hosts of *Physaloptera* species. Cats can contract the disease by consuming intermediate hosts that have been affected by *Physaloptera* spp. larvae or by consuming paratenic hosts that have already consumed an intermediate host, like mice (Taylor *et al.*, 2015). These nematodes adhere tightly to the mucosa of the stomach and duodenum after ingestion, where they begin to feed on blood (Naem and Asadi, 2013).

Although *Physaloptera* species are found all over the world, North and South America, Australia, and Asia account for the majority of cases of infections in cats and dogs. Few reports of *Physaloptera* spp. in domestic dogs and cats have been made in Europe and Africa (Jennifer *et al.*, 2021). Some researchers have reported *P. rara* to be the most common *Physaloptera* species to parasitize dogs and cats (Burrows, 1983). Necropsies of stray cats and dogs revealed prevalences of 1% to 25% and 1% to 28%, respectively. A faecal flotation study of dogs in Iowa found a prevalence rate of 1.6% (Loebenberg and Waitz, 1977). A study on 6458 faecal samples from dogs in U.S. animal shelters found a 0.1% prevalence rate for *Physaloptera* eggs (Levine, 1980). A study from Pubela city, Mexico, revealed a 0.4% prevalence of *Physaloptera* spp. in dogs (Contreas-Flores *et al*., 2021), and Raji *et al*. (2013) indicated a 3.3% prevalence of *Physaloptera* spp. in cats of Sokoto, Nigeria. From Ethiopia, Nateneal *et al*. (2015) recorded a 1.1% prevalence of *Physaloptera* spp. in dogs of Haramaya town.

2.2.2. Life cycle

At the beginning of their life cycle, adult male and female hookworms mate in the intestine (Figure 1 and Table 4). After that, the mature female lays eggs. The host excretes the eggs in the faces, and they usually hatch into larvae with a non-living cuticle layer in a day on warm, moist soil. After two to four days, the larvae have undergone two moults and are ready to infect a host. From the faeces, migration takes place into the nearby soil. There are two ways that the environment can infect hosts. The first pathway entails skin penetration at sweat glands or hair follicles, particularly between the footpads where the skin is thinner than usual and frequent contact with soil occurs. It is believed that *A. caninum* facilitates this process by secreting a protease. After that, the larvae go through the skin's dermis, enter the bloodstream, and travel to the lungs. Larvae of *A. caninum* leave the bloodstream at the lungs, ascend through the trachea from the alveoli, and then find their way into the intestine (Marquardt and Demaree, 2000).

Although direct host ingestion of *A. caninum* is the second and more popular route to the small intestine, the ensuing procedure is the same in both situations. The establishment of the larva's male or female reproductive organs occurs during the third stage. The adult form of *A. caninum* is produced by a third and final moult, after which it consumes the mucosa and blood of the small intestine wall. To finish the cycle, sexual reproduction also takes place in the intestine to create another set of eggs (Landmann and Prociv, 2003).

There is also the possibility of direct transmission between hosts. When larvae enter the body through the skin, they may resist leaving through the lungs and continue to circulate throughout the body. At the uterine artery of a pregnant female, the larvae can cross the placenta to cause prenatal infection of foetuses. As previously described, the larvae of an infected foetus move to the liver until birth, migration continues with movement to the intestine via the circulation and lungs. Alternatively, instead of leaving the circulation at the lungs, *A. caninum* larvae may be transported to the mammary glands and passed from the mother to her pups in the form of milk or colostrum; infection then occurs in the same way as if the infection had been ingested from the surroundings. Prenatal transmission from infected mothers to pups has been observed to occur infrequently, although lactational infection during nursing is significantly more likely (Burke and Roberson, 1985).

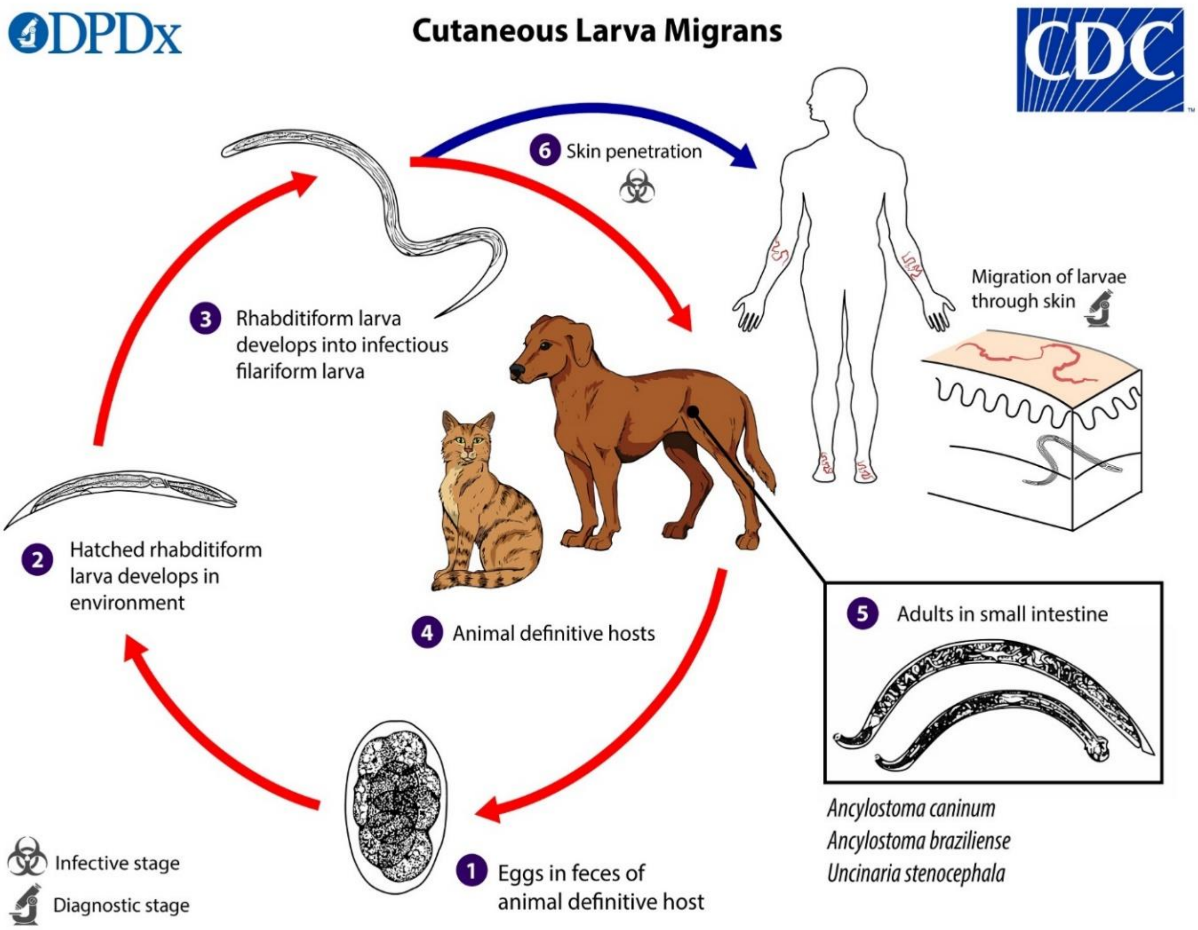

Figure 1. Life cycle of *Ancylostoma* species (CDC, 2019).

Both *T. canis* and *T. cati* have intricate life cycles. Large quantities of eggs are released into the environment by adult worms in the digestive tracts of infected dogs and cats through their faeces, where they are consumed by both natural and paratenic hosts (Figure 2 and Table 4). The egg hatch in the intestine and travel throughout the body via blood arteries. Visceral larva migrans is the term for this. After swallowing, a tracheal migration takes place in young animals through the lungs and trachea, the larvae mature in the intestinal tract. After predation of *Toxocara* infected paratenic hosts by dogs or cats, larvae will be released and develop, in most cases directly to adult worms in the intestinal tract. In the pregnant bitch and queen, 'dormant' tissue larvae are reactivated and migrate in the bitch across the placenta to infect the foetuses. By consuming the larvae in the milk, newborn puppies and kittens can also get infected (Parsons, 1987). Unlike in puppies, kittens are primarily infected with *T. cati* through the transmamary pathway. The kitten develops larvae that are transferred through colostrum or milk without tracheal migration (Overgaauw, 1997).

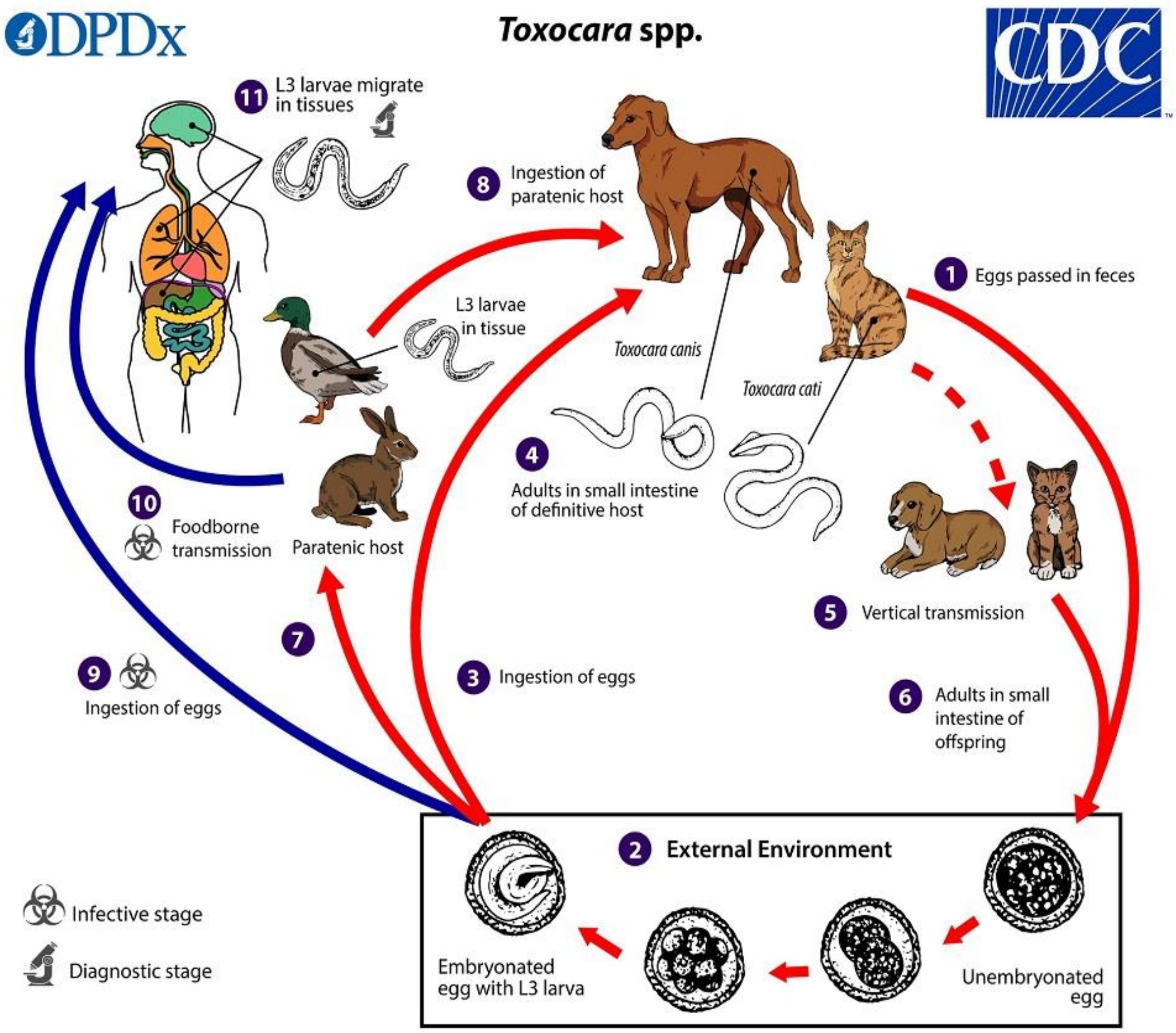

Figure 2. The life cycle of *Toxocara canis* and *Toxocara cati* (CDC, 2014).

Only female *S. stercoralis* worms are parasitic during their intricate life cycle. The adult females reproduce asexually through parthenogenesis, releasing eggs into the gut lumen, while implanted in the intestinal mucosa. In the intestine, first-stage larvae (L1; rhabditiform larvae) hatch and either develop straight into the second and infectious third-stage larvae (L3; filariform larvae) or are expelled with the faeces. The L1 shed with faeces may develop into L3 in the soil within 24 hours. The infectious L3 can penetrate the epidermis of the vulnerable host, be swallowed, enter the airways and then travel to the intestine, where they infiltrate the mucosa and develop into adult females. As an alternative, hosts may contract L3 in a less significant epidemiological context through transmamary transmission. Furthermore, when L1 has already transformed into L3 in the intestine and re-infects its host by penetrating the intestinal mucosa or the perianal skin, autoinfections occur (Deplazes *et al*., 2016).

Because of their indirect life cycle, *Physaloptera* species need an intermediary host in order to mature into the infectious stage. Ingestion of eggs found in the environment cannot infect definitive hosts, which are carnivorous animals. According to Santen *et al*. (1993), infectious eggs from infected definitive hosts can endure for 40 days at room temperature or 60 days at 4˚C. The eggs are consumed by suitable intermediate hosts, such as cockroaches, flour beetles, and ground beetles. After hatching in the intermediate host's intestines, first-stage larvae go to the intestines' outer layers, encyst, and subsequently moult to second-stage larvae in 11-16 days. They moult to the infectious third stage after another 12 days (Levine, 1980). The intermediate host is subsequently consumed by either a definitive (such as a dog or cat) or paratenic (such as frogs, snakes, or mice) host. Ingesting paratenic hosts can potentially infect dogs and cats. According to Santen *et al*. (1993), larvae do not move from the intestinal or stomach mucosa of definitive hosts. Adults grow and adhere to the mucosa of the stomach or duodenum. It takes 56-83 days for infectious larvae to mature into adults that deposit eggs. According to Hendrix and Blagburn (1983), eggs are released through the faeces of definitive hosts.

Table 4. Common nematode parasites of dogs and cats: life cycle overview.

Parasite	Definitive Host(s)	Transmission Route	Life Cycle Type	Key Life Cycle Stages	Intermediate Host (if any)
Toxocara canis	Dog	Ingestion of eggs, transplacental, transmammary	Direct & transplacental	Egg → Larva in egg → Ingestion → Hepatic-tracheal migration → Adult in small intestine	None
Toxocara cati	Cat	Ingestion of eggs, paratenic host, transmammary	Direct & transmammary	Egg → Larva in egg → Ingestion → Migration → Adult in small intestine	Paratenic (e.g., rodents)
Toxascaris leonina	Dog and Cat	Ingestion of eggs or paratenic host	Direct	Egg → Larva in egg → Ingestion → Mucosal migration → Adult in small intestine	Paratenic
Ancylostoma caninum	Dog	Skin penetration, ingestion, transmammary	Direct	Egg → L1 → L2 → Infective L3 → Skin/oral → Migration → Adult in small intestine	None
Ancylostoma tubaeforme	Cat	Skin penetration, ingestion	Direct	Egg → L1 → L2 → L3 → Skin/oral → Migration → Adult in small intestine	None
Uncinaria stenocephala	Dog and Cat	Ingestion of L3 larvae	Direct	Egg → L1 → L2 → L3 → Ingestion → Adult in small intestine	None
Trichuris vulpis	Dog	Ingestion of embryonated eggs	Direct	Egg → Larva in egg → Ingestion → Maturation in cecum/colon	None
Physaloptera spp.	Dog and Cat	Ingestion of infected intermediate/paretenic host	Indirect	Eggs are ingested by insects (e.g., beetles, cockroaches, crickets), which act as intermediate hosts. Infected insects may be eaten by paratenic hosts (e.g., birds, rodents, reptiles), where larvae encyst. Dogs or cats become infected by ingesting intermediate or paratenic hosts.	Insects (e.g., beetles, cockroaches, crickets), paratenic hosts
Strongyloides stercoralis	Dog	Skin penetration, transmammary, autoinfection	Direct with free-living stage	Larva → Skin penetration → Lung migration → Adult female in small intestine	None

Source: ESCCAP (2025).

2.2.3. Clinical manifestations

Hookworms' primary veterinary significance stems from their capacity to draw blood from their primary host. Multiple lacerations related to mating and the worms' numerous movements and reattachments also cause damage to the intestinal mucosa. The most significant distinction between the species in terms of morbidity is that *A. caninum* results in significantly more blood loss than either *A. ceylanicum* or *A. braziliense* (Landmann and Prociv, 2003). However, the host's age, nutritional condition, and worm burden all have a significant impact on how severe the clinical symptoms are. Even mild to moderate *A. caninum* infections in puppies and immunocompromised hosts can cause severe anemia, hypoproteinemia, and bloody diarrhea, and they can even be fatal. In immunocompetent adult dogs, a more chronic and often subclinical disease manifests, producing iron deficiency anaemia, general malaise, a dull hair coat and poor physical condition. Acanthosis and hyperkeratinization are characteristics of skin lesions caused by cutaneous larva migrants, and the interdigital skin is where newly passing larvae most frequently leave serpentine tracks (Reinemeyer, 1995).

The number, location, and developmental stage of the worms, as well as the age of the animal, determine how *Toxocara* affects dogs and cats. According to Peter and Rebecca (2006), a toxocara infection in young or adult dogs and cats with mild infections is often asymptomatic or just linked to a failure to acquire weight. Puppies and kittens up to six months of age are most susceptible to toxocara infection (Overgaauw, 1997).

Although it has never been documented in other investigations, it is hypothesized that prenatal infections in puppies cause stillbirths and premature deaths. Puppies may die within two to three days after birth from pneumonia linked to the tracheal migration. Puppies may exhibit emaciation and digestive issues between the ages of two and three weeks, which are brought on by mature worms in the stomach and intestine. Clinical examination may reveal symptoms such as coughing, nasal discharge, vomiting, diarrhea, and constipation. Abdominal distension, or "potbelly," may happen, most likely as a result of gas production brought on by dysbacteriosis. Blockage of the pancreatic duct, bile duct, gall bladder, and intestinal perforation can all result in death (Parsons, 1987).

Since transmamary infection is the only significant source of infection in kittens, the situation differs from that of puppies. Because of this, clinical symptoms that resemble those of puppies are typically not noticeable and manifest later in life (Overgaauw, 1997). Adult cats with more serious intestinal infections may exhibit symptoms of dehydration, a potbelly, and a rough coat (Parsons, 1987).

According to reports, canine strongyloidosis is a common issue in breeding kennels, especially during hot and humid weather (Hendrix *et al*., 1987). Large parasite infections cause clinical symptoms in puppies, but even with enormous worm loads, adult dogs may show no symptoms (Dillard *et al*., 2007). Pathogenesis is related to the establishment of adult females in the small intestine, where the epithelium gets flatter due to their settlement at the base of the villi and, partially, in the intestinal glands, leading to diarrhoea (Deplazes *et al*., 2016). Through the progression of L1 to L3 in the intestine, autoinfections may promote enteritis, resulting in chronically infected or even hyperinfected hosts, where L3 may also transfer to other body regions. Migrating larvae, in particular, can induce local inflammations and hemorrhages in the lungs, which can result in bronchopneumonia, coughing, and dyspnea (Schad *et al*., 1984).

Physaloptera species can infect dogs and cats of any breed or age. Animals are more susceptible to infection the more time they spend outside. Intermittent vomiting, which can persist for a few weeks to many months, is the most typical clinical symptom. Lethargy, melena, weight loss, diarrhea, regurgitation, and anorexia are other clinical symptoms (Gustafson, 1995). The majority of patients continue to have a healthy appetite and a comparatively normal level of energy. It is challenging to extrapolate data regarding clinical indicators because there are few reports of clinical disease in cats. However, case reports suggest that cats infected with *Physaloptera* may be more susceptible to melena or diarrhea (Santen *et al.*, 1993). The gastric mucosa is harmed by the stomach worms, which results in gastritis, bleeding, and persistent vomiting. Anaemia and weight loss are symptoms of a serious infection. In cats with *Physaloptera* spp., the most prevalent clinical symptom is chronic intermittent vomiting (Thiesen *et al*., 1998).

2.3. Cestodes

Cestodes are hermaphrodite flatworms with repeated segments, a neck area, and a scolex. Cestodes have no body cavity, gut, or mouth. The tapeworm's life cycle is indirect; the definitive host obtains the adult form by consuming the larval metacestode stage that is present in an intermediate host. Typically, this process occurs in the form of a predator-prey dynamic. Dogs and cats frequently get cestode infections, which can be caused by a variety of species, including pseudophyllidean (*Diphyllobothrium, Spirometra*) and cyclophyllidean (*Taenia, Dipylidium, Mesocestoides, Echinococcus*) tapeworms. According to Conboy (2009), dogs and cats are the most common definitive hosts, meaning they carry the adult tapeworms in their small intestine. Taeniids are widely distributed around the world and use a variety of mammalian species in their life cycles, which can pose a risk to people and pets as well as lower livestock productivity (Lee *et al*., 2016).

2.3.1. Epidemiology

As indicated in table 5, tapeworm infection in dogs is endemic in parts of Europe, Africa, South and North America, the Middle East, and Asia (Deplazes *et al*., 2017). The chance that a certain dog or cat can contract tapeworms depends on several factors, such as the animal's geographic location and the chance that it will consume an infected intermediate host (Blagburn, 2001). Dogs contract taeniid tapeworms by eating the larval stages of the parasites, which are found in the liver or lungs of ruminants and pigs. Within 1-3 months, the adult worms begin to mature in the small intestine (Thompson and Lymbery, 1995).

The incidence of tapeworms in the Americas ranges from 1.8% to 52.7% in cats and from 4% to 60% in dogs (Eguia-Aguilar *et al*., 2005). The frequency of infection with *Dipylidium* (*D.*) *caninum* and *Taenia* species is most likely underestimated by prevalence estimates derived solely from faecal flotation. Even when an infection is present, a particular faecal sample may not contain tapeworm proglottids or eggs due to the focused distribution of proglottids and eggs in faecal material (Blagburn, 2001). Although *Mesocestoides* species are less prevalent than *Taenia* or *D. caninum* species, they do occasionally show up in global foci (Kazacos, 2003). Infections with *Spirometra* and *Diphyllobothrium* species are less frequent in dogs and cats than infections with Cyclophyllidean cestodes, and the incidence of these parasites has not been well studied (Deplazes *et al*., 2017).

Table 5. Reports on prevalence rates of *Taenia* spp. of dog and cat from various regions of the world.

Country	Rate of Infection (%)		Lab. techniques used	References
	Dog	Cat		
Port Alegre, Brazil	1.8	3.4	Floatation technique	Gustavo *et al.* (2007)
İstanbul, Turkey	4	-	Floatation technique	Kerem *et al*. (2011)
Bahir Dar town, Ethiopia	26.6	-	Floatation and sedimentation methods	Zelalem and Mekonnen (2012)
Al-Diwaniya province, Iraq	-	4.7	Formalin-ether sedimentation and floatation techniques	Hussam (2015)
Samsun, Turkey	0.4	0.2	Floatation technique	Ali *et al*. (2015)
Adama town, Ethiopia	0.5	-	Faecal flotation and sedimentation techniques	Tolera and Berhanu (2015)
Mekelle town, Ethiopia	41.1	-	Floatation technique	Getachew *et al*. (2015)
Mexico	3.9	-	Floatation technique	Enrique *et al*. (2017)
Nairobi, Kenya	0.1	-	Modified Mc Master technique	Wyckliff *et al*. (2017)
Cebu, Philippines	3	-	Floatation technique	Urgel *et al.* (2019
Jos Metropolis-Nigeria	5.3	-	Faecal floatation and sedimentation techniques	Amapu *et al.* (2019)
Hosanna Town, Ethiopia	4.2	-	Faecal floatation and sedimentation techniques	Yimer *et al*. (2019)
Wondo Genet, Ethiopia	74.7	-	Kato-Katz methodology	Octavius *et al*. (2019)
Chagni town, Ethiopia	94.6	-	Kato-Katz methodology	Nigatu (2019)
Jimma town, Ethiopia	46	-	Floatation technique	Hailu *et al*. (2019)
Kashmir Valley, India	-	22.5	Faecal floatation and sedimentation techniques	Mohmad *et al*. (2020)
Basrah, Iraq	10.5	-	Direct faecal smears examination	Abdulhameed *et al*. (2020)

Dipylidium caninum cestodes live in the small intestine and infect primarily dogs and cats, as well as humans. The parasite life cycle requires larval stages of fleas or possibly biting lice as intermediate hosts. By inadvertently consuming adult fleas or lice carrying the parasite's cysticercoid stage, dogs, cats, and humans, particularly children, can contract the infection (Chelladurai *et al*., 2018). Around the world, *Dipylidium* (*D.*) *caninum* is found in both insects, such as fleas and lice, and vertebrates, including humans (Low *et al*., 2017). Given that invertebrate intermediate hosts are also prevalent worldwide and since fleas are the most common ectoparasite of dogs and cats, the parasite's broad geographic distribution is not surprising (Bronstein *et al*., 2020). Climate change, coupled with increased urbanisation and the increased number of pets may affect the prevalence and endemicity of the intermediate hosts (Rust, 2017). The vertebrate species and its lifestyle may have an impact on the risk of contracting *D. caninum*. Animals from shelters and stray populations are more susceptible to illness because they are less likely to have access to veterinary care. *Dipylidium* caninum infection is more likely to occur in dogs and cats that are flea or lice-infested (ESCCAP, 2021).

According to Beugnet *et al*. (2018), the proportion of fleas carrying the parasite was higher in dogs. Compared to dogs, cats may consume more fleas due to their more noticeable grooming habits, which could increase their chance of contracting *D. caninum*. Nonetheless, it has been noted that cats exhibit reduced levels of *D. caninum* parasitism (Garcia-Agudo *et al*., 2014).

According to published research, the prevalence of *D. caninum* in dogs ranges from 4% to 60%, whereas in cats, it ranges from 1.8% to 52.7%. Compared to surveys that solely report faecal floatation, estimates based on direct examination of the small intestine are more accurate and typically yield a substantially higher prevalence (Raether and Hänel, 2003). Because proglottids (and thus eggs) are focally distributed in faecal material and because eggs are heavy and therefore do not readily float, prevalence data derived from faecal flotation alone most likely underestimate the frequency of infection with Cyclophyllidean cestodes, including *D. caninum* (Adolph *et al*., 2015). As indicated in table 6, studies conducted in Ethiopia revealed significant variation in the prevalence of *D. caninum*, especially in dogs, which ranged from 6.6% to 71%.

Table 6. Reports on prevalence rates of *Dipylidium caninum* of dog and cat from various regions of the world.

Country	Rate of Infection (%)		Lab. techniques used	References
	Dog	Cat		
Porto Alegre, Brazil	5.9	6.8	Floatation technique	Gustavo *et al*. (2007)
Ambo town, Ethiopia	71.2	-	Floatation and sedimentation techniques	Endrias *et al*. (2010)
Hawassa town, Ethiopia	39.9	-	Sedimentation and flotation techniques	Dagmawi *et al*. (2012)
Hawassa town, Ethiopia	34.3	-	Mc master egg counting and sedimentation techniques	Dejene *et al*. (2013)
Malaysia	4.7	8	Standard direct smear and formalin ethyl acetate concentration techniques	Romano *et al*. (2014)
Nakhon Nayok, Thailand	0.2	-	Formalin-ether concentration technique	Wichit *et al*. (2014)
Northern Italy	2.9	4.5	Centrifugation-flotation technique	Sergio *et al*. (2014)
Adama town, Ethiopia	23.7	-	Faecal flotation and sedimentation techniques	Tolera and Berhanu (2015)
Mekelle town, Ethiopia	37.7	-	Floatation technique	Getachew et al. (2015)
Harar town, Ethiopia	2.1	2.6	Floatation technique	Nateneal et al. (2015)
Nairobi, Kenya	0.4	-	Modified Mc Master technique	Wyckliff *et al*. (2017)
Chagni town, North-western Ethiopia	61.4	-	Kato-Katz methodology	Nigatu (2019)
Jimma town, Ethiopia	28.8	-	Floatation technique	Hailu *et al*. (2019)
Wondo Genet, Ethiopia	46.8	-	Kato-Katz methodology	Octavius *et al*. (2019)
Bishoftu town, Ethiopia	19.8	-	Floatation technique	Mitiku *et al*. (2020)
Bishoftu town, Ethiopia	21	-	Floatation technique	Gutema *et al*. (2021)
Plateau State, Nigeria	1.9	-	Floatation technique	Karaye *et al*. (2021)
Hawassa town, Ethiopia	4.4	-	Floatation technique	Teshager *et al*. (2023)

Humans and animals are the definitive hosts of diphyllobothriosis, but several fish species are intermediate or paratenic hosts. According to Rivero *et al.* (2015), *Diphyllobothrium latum* (Linnaeus 1785), commonly referred to as fish tapeworm or broad tapeworm, is a member of the *Pseudophyllidea* order that is found around the world. In many regions of the world, particularly the northern hemisphere, adult cestodes of the genus *Diphyllobothrium* (*D.*)

reside in the small intestine of dogs, as well as other fish-eating mammals and birds. Cats and dogs can get infected with *Diphyllobothrium* species. Dogs and cats can become infected with *Diphyllobothrium* spp. after consuming an infected fish that consumed the copepod as a first intermediate host and a fish as a second intermediate host. Three to four weeks after infection, dogs and cats may start to shed *D. latum* eggs. Only when dogs and cats consume fish larvae in an area where infections are naturally occurring can infections result (Conboy, 2009).

Raw or smoked fish is the main source of infection (Vafae *et al*., 2022). It is important not to undervalue the part that dogs play in the spread of *Diphyllobothrium* sp., mostly by faecal contamination of water. Furthermore, it should be noted that fishermen frequently feed dogs the viscera of infected fish (María *et al*., 2015).

Diphyllobothrium species can be found all over the world, with concentrations in Asia, North and South America, and Europe. With a wide host specificity, diphyllobothrium tapeworms are primarily found in tropical and sub-tropical regions, with Southeast Asia and Africa having the highest prevalence (Waeschenbach *et al*., 2017). *Diphyllobothrium* spp. infections in dogs and cats are less frequent than those caused by *Cyclophyllidean* cestodes (Conboy, 2009), and Vafae *et al*. (2022) recorded a pooled prevalence *Diphyllobothrium* infection in dogs as 0.06%. From Ethiopia, Abere *et al*. (2013) recorded a 10.3% prevalence of *D. latum* in dogs of Bahir Dar town (Table 7).

Table 7. Reports on prevalence rates of *Diphyllobothrium latum* in dog of various regions of the world.

Country	Rate of Infection (%)	Lab. techniques used	References
Bahir Dar town, Ethiopia	10.3	Direct smear, sedimentation and floatation techniques	Abere *et al*. (2013)
Ashanti, Ghana	7.2	Flotation technique	Papa *et al*. (2016)
India	0.7	Floatation and sedimentation techniques	Roja *et al*. (2020)
Nigeria	12.7	Flotation technique	Ogbu *et al*. (2021)
Uzbekistan	31.6	Direct smear, sedimentation and floatation techniques	Safarov *et al*. (2022)

2.3.2. Life cycle

The indirect life cycles of all cestodes necessitate particular intermediary hosts (Table 8). In dogs and cats, the *Cyclophyllidean* tapeworms, often known as real tapeworms, are more prevalent than the *Pseudophyllidean,* the other major category of cestodes. Faeces containing egg-laden proglottids are excreted by dogs and cats infected with adult *Cyclophyllidean* tapeworms, such as *Mesocestoides, Echinococcus species, Dipylidium caninum or Taenia*. Taeniid eggs can survive on pasture, in soil and water following contamination with infected dog faeces and subsequently wind and wildlife can disperse the eggs over long distances. The eggs hatch in the small intestine and pass through the intestinal wall after being consumed by the intermediate host. They then spread to organs, including the liver and lungs, via the circulatory system, where they either grow into cysts or metacestodes (larval stage) (Garrido *et al*., 2007).

When dogs and cats consume the intermediate host that harbours these larval cysts, they become infected. As soon as two or three weeks after infection, these pets may start to shed proglottids of *Mesocestoides* or *D. caninum* species. According to Bowman *et al*. (2003), the prepatent period for *Taenia* and *Echinococcus* species might last up to one or two months.

Adult pseudophyllidean cestodes, such as *Diphyllobothrium latum* and *Spirometra* species, on the other hand, release individual operculated eggs via a median genital pore. After hatching in water, these eggs develop in a copepod as their first intermediate host and then a vertebrate as their second intermediate host. Eventually, they are consumed by a cat or dog as their definitive host and mature into adult tapeworms. As soon as ten days after infection, dogs and cats may start to discharge pseudophyllidean tapeworm eggs. Dogs and cats will only become infected if they consume larvae from prey species or undercooked animal tissue in a region where infections are naturally occurring (Bowman *et al*., 2003).

Table 8. Life cycle of common cestodes in dogs and cats.

Cestode Species	Definitive Host	Intermediate Host	Transmission Route	Site of Adult Worm	Key Notes
Dipylidium caninum	Dog, Cat	Flea (*Ctenocephalides* spp.), Lice	Ingestion of infected flea or louse containing *cysticercoid* larva	Small intestine	Most common; "rice-grain" proglottids seen in feces or near anus
Taenia pisiformis	Dog	Rabbit	Dog ingests infected rabbit tissues containing *cysticercus* larva	Small intestine	Proglottids are rectangular and motile; uncommon in cats
Taenia taeniaeformis	Cat	Rodents	Cat ingests infected rodent with *strobilocercus* larva	Small intestine	Common in outdoor/hunting cats
Echinococcus granulosus	Dog	Sheep, deer, other ungulates	Dog eats organs of infected intermediate host containing hydatid cysts	Small intestine	Zoonotic; causes hydatid disease in humans
Echinococcus multilocularis	Dog, Cat	Rodents	Ingestion of infected rodents with alveolar hydatid cysts	Small intestine	Zoonotic; more dangerous due to invasive cyst growth in humans
Taenia hydatigena	Dog	Livestock (e.g., sheep, pigs)	Ingestion of infected liver or peritoneal tissues of intermediate host	Small intestine	Found more in rural or hunting dogs
Taenia ovis	Dog	Sheep	Ingestion of infected muscles (striated muscle) by *Cysticercus ovis*	Small intestine	
Taenia multiceps	Dog	Sheep, goats	Ingestion of infected brain or spinal cord by *Coenurus cerebralis*	Small intestine	

Source: CDC (2019).

2.3.3. Clinical manifestations

Although the common cestodes of dogs and cats, such as *D. caninum* and *Taenia* species, normally do not cause major disease in pets (Bowman *et al*., 2003), tapeworm infestations are cosmetically unappealing. In addition to providing a zoonotic health concern in the home, proglottids on pets or in the house can upset animal owners and sever the human-animal link. On the other hand, peritoneal cestodiasis can occasionally be caused by the less frequent *Mesocestoides* species (Little and Ambrose, 2000).

Rarely, dogs and cats can contract *Taenia's* metacestode stages of infection. There have been seven documented cases of *T. serialis*-induced cerebral coenurosis in cats in North America (Huss *et al*., 1994). When a coenuri is found in the brain after necropsy, it is always possible to diagnose an infected cat with evidence of severe central nervous system disease (Conboy, 2009). Both *Diphyllobothrium* and *Spirometra* species have been linked to gastrointestinal disorders in dogs and cats that manifest as vomiting, diarrhea, and weight loss (Little and Ambrose, 2000).

2.4. Protozoa

Protozoa are single-celled organisms and are frequently observed living freely in the environment. Certain species can infect mammals, such as dogs and cats, and either cause illness or remain asymptomatic and tolerated by the host. The disease, which can range from diarrhea and weight loss to debilitation and even death, is more prevalent in young or debilitated animals. They are frequently categorized as extraintestinal or gastrointestinal. Diagnosing these parasite diseases may be the most difficult part of managing them. Infectious form shedding may be sporadic and can be hard to spot (Libby, 2022).

2.4.1. Epidemiology

A wide range of intestinal protozoa commonly infects dogs and cats throughout the world, including *Giardia duodenalis*, *Cystoisospora* spp. and *Cryptosporidium* spp. (Mircean *et al.,* 2010). In developing nations, giardiasis is thought to be the most common intestinal parasite infection among companion pets, such as dogs and cats. *Giardia* species are identified based on the morphology of the trophozoites and the host's origin, primarily by the appearance of the median bodies. They are members of the phylum *Fornicata*, class *Trepomonadea*, family *Giardidae* (Dantas-Torres and Otranto, 2014). Humans and several animal species are infected with the extracellular protozoan gut parasite *Giardia* (*G.*) *duodenalis* (Perrucci *et al*., 2020).

Recently, the species have been grouped into assemblages using molecular methods: people, dogs, cats, farm animals, primates, rodents, and other wild mammals can all contract *Giardia duodenalis* (Assemblage A) parasites. Humans, dogs, cats, primates, and certain wild mammals are all parasitized by *Giardia interica* (Assemblage B). Dogs and other canids are parasitized by *Giardia canis* (Assemblages C, D). Cat parasites caused by *Giardia cati* (Assemblage F) (Ryan *et al*., 2017). Assemblages A and B can spread zoonotically, have a broad host specificity, and have a tendency to infect people (Thompson *et al*., 2008). The faecal-oral pathway, polluted water, fomites (such as fur and contaminated housing), and the environment are how the *Giardia* parasite can spread. Perrucci *et al*. (2020) stated that giardiasis is the most prevalent acute or chronic parasite diarrheal illness in dogs and cats globally. Prevalence rates and excretion patterns determine the degree of danger (Caccio *et al*., 2005).

Worldwide, reports of giardiasis in companion dogs vary in frequency (McDowall *et al*., 2011). Due to unsanitary conditions and favourable climates, the parasite can be highly endemic. The prevalence varies among studies based on geographic locations, local animal habitat, detection technique, animal age, symptom status, and season (Ballweber *et al*., 2010; Kostopoulou *et al*., 2017). The more often anthelmintic medication is administered, the higher the chance of *Giardia* infection. This is most likely because anthelmintics' effects on important parasites, such as ascarids and hookworms, cause a niche in the intestine to vacation (Bugg *et al*., 1999). It has been observed that stray dogs and cats have a higher frequency of these protozoan parasites than do pets (Kostopoulou *et al*., 2017).

In domestic dogs, females were more likely than males to be infected with intestinal parasites, such as *Giardia* (33.3%), according to Jasim and Faraj (2018). The prevalence in dogs less than six months was 44.4%, while in dogs more than six months was 20%. The overall infection rate among cats in North America is as high as 4% (Marks, 2016). Kittens younger than 1 year are at increased risk for infection (Lappin, 2014). The previous reports on prevalence rates of *Giardia* species in various regions of the world are indicated in table 9.

Table 9. Reports on prevalence rates of *Giardia* species in dogs and cats of various regions of the world.

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Nakhon Nayok, Thailand	*G. duodenalis*	2.8	0.3	Formalin-ether concentration	Wichit *et al*. (2014)
Porto Alegre, Brazil	*Giardia* spp.	4.5	3.5	Flotation technique	Gustavo *et al*. (2007)
Northern Italy	*G. duodenalis*	16	22.5	Centrifugation-flotation technique	Sergio *et al*. (2014)
Malaysia	*G. duodenalis*	13	10.7	Standard direct smear formalin ethyl acetate concentration technique	Romano *et al*. (2014)
North-western Spain	*Giardia* spp.	27.3	7.7	Commercial immunofluorescent assay	Remesar *et al*. (2011)
Iraq	*Giardia* spp.	-	9.3	Formalin-ether sedimentation method and floatation technique	Hussam (2015)
Egypt	*Giardia* spp.	31.7	-	Centrifugal faecal floatation technique and formalin-ether sedimentation techniques	Ahmed *et al*. (2014)
Morocco	*Giardia* spp.	7.2	-	Centrifugal flotation technique	Houda *et al*. (2022)
Nigeria	*Giardia* spp.	7.3	-	Formalin-ether sedimentation and floatation techniques	Amapu *et al*. (2019)

Worldwide, a variety of highly host-specific species of *Cystoisospora* (*C*.), formerly known as *Isospora* (*I*.), frequently infect dogs and cats, particularly puppies and kittens (Dubey, 2009). *Isospora canis, I. ohioensis,* and *I. burrowsi* are the three main species that infect dogs; *I. neorivolta* is less frequently documented. *Isospora* is found all around the world (Lindsay *et al*., 1997). The species that infect domestic cats are *Cystoisospora felis* and *C. rivolta* (Guzmán *et al*., 2020). Bradyzoites in the tissues of small animal paratenic hosts or sporulated oocysts in the environment can infect cats and dogs (Dubey, 2009). *Isospora* spp. are host-specific, have worldwide distribution and infections are very common, particularly in young animals. In a study on 1355 cats in the United Kingdom, *I. felis* oocysts were detected with a proportion of 3%. Gender and breed do not usually influence the *Isospora* spp. shedding rates, but young animals are usually more likely to be shedding oocysts than adults (Tzannes *et al*., 2008). This parasite is more likely to infect animals that are under stress or have impaired immune systems, as well as animals that reside in crowded, unsanitary environments (Ramos *et al*., 2016).

Using the modified McMaster approach, a study conducted in the Republic of Ghana found that 8.6% of the participants had the parasite (Johnson *et al*., 2015). According to a study conducted on dogs in a rural area of western Uganda, 97.1% of them had intestinal parasites, and 13.3% had *Isospora* spp. identified by microscopy using the flotation-sedimentation technique (Hyeroba *et al*., 2017). In Brazil, 1.5% of dog faecal samples treated with flotation and centrifugation-sedimentation methods tested positive for *Isospora* spp. (Ferreira *et al*., 2016). Table 10 lists more prior reports on *Isospora* spp. prevalence rates in different parts of the world.

Table 10. Reports on prevalence rates of *Isospora (Cystoisospora)* species in dogs and cats of various regions of the world.

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Porto Alegre, Brazil	*Isospora* spp.	31.9	27.1	Flotation technique	Gustavo *et al*. (2007)
Thailand	*I. felis*	-	1	Formalin ethyl acetate centrifugal sedimentation technique	Sathaporn *et al*. (2007)
Iran	*Isospora* spp.	24.3	-	Formalin-ether sedimentation method	Alimohammad *et al*. (2011)
Sokoto, Nigeria	*Isospora* spp.	-	13.3	Formol-ether and floatation technique	Raji *et al*. (2013)
Egypt	*C. canis*	3.3	-	Centrifugal faecal floatation technique and formol ether sedimentation techniques	Ahmed *et al*. (2014)
Nakhon Nayok, Thailand	*Isospora* spp.	-	5.7	Formalin-ether concentration technique	Wichit *et al*. (2014)
Northern Italy	*Isospora* spp.	3.7	5.3	Centrifugation-flotation technique	Sergio *et al*. (2014)
Malaysia	*Isospora* spp.	1.3	3.4	Standard direct smear, formalin ethyl acetate concentration technique s	Romano *et al*. (2014)

Table 10 (Continued)

Country	Species identified	Rate of Infection (%)		Lab. techniques used	References
		Dog	Cat		
Iraq	*Isospora* spp.	-	7	Formalin-ether sedimentation method and floatation technique and stained with trichome iodine stains	Hussam (2015)
Mexico	*Cystoisospora* spp.	4.4	-	Flotation technique	Enrique *et al*. (2017)
Poland	*Cystoisospora* oocysts	24.2	-	Mini Parasep®SF faecal parasite concentrator (Diasys Europe Ltd.)	Szwabe and Błaszkowska (2017)
Rio de Janeiro, Brazil	*C. felis* *C. rivolta*	- -	4.4 16.5	Centrifugal sedimentation and flotation techniques	Pâmela *et al*. (2017)
Rio de Janeiro, Brazil	*C. canis* *C. ohioensis* complex *C. felis*	1.8 0.3 -	- - 4.8	Centrifugal flotation technique	Igor Falco *et al*. (2021)
Puebla City, Mexico	*Cystoisospora* spp.	4	-	Flotation technique	Contreras-Flores *et al*. (2021)
Morocco	*Cystoisospora* spp.	7.2	-	Centrifugal flotation technique	Houda *et al*. (2022)

2.4.2. Life cycle

All *Giardia* species have a direct life cycle (Figure 4 and Table 11) (Kirkpatrick, 1987). A host consumes cysts through their faeces or through faecal-contaminated food or water. After the cysts are exposed to pancreatic enzymes and stomach acid, excystment takes place in the duodenum. The excyzoite, a recently excysted cell, splits twice to produce four trophozoites, each of which has two diploid nuclei that contain multiple copies of the five chromosomes (Bernander *et al*., 2001). The trophozoites, which have an anaerobic metabolism, typically adhere to the basal side of the brush border of the proximal small intestine and use the cell membrane to absorb nutrition (Kirkpatrick, 1987). The relatively huge numbers of trophozoites found in a normal infection are produced by simple binary fission. At some point, some trophozoites encyst for the purpose of transmission because the unprotected trophozoites are incapable of causing infection and die if released into the environment

(Bowman *et al*., 2003). Although its precise location is unknown, encystation most likely takes place in the colon or ileum (Kirkpatrick, 1987).

Although trophozoites are rarely discharged, particularly in hypermotile guts that expel them before they have a chance to encyst, cysts are the stage that is typically evacuated in faeces. Through a process called autoinfection, the cysts that are discharged in the faeces might be consumed by either the same host or a different host. It has been established that the prepatent period in experimentally infected animals ranges from 5 to 10 days for dogs and up to 16 days for cats (Bowman *et al*., 2002).

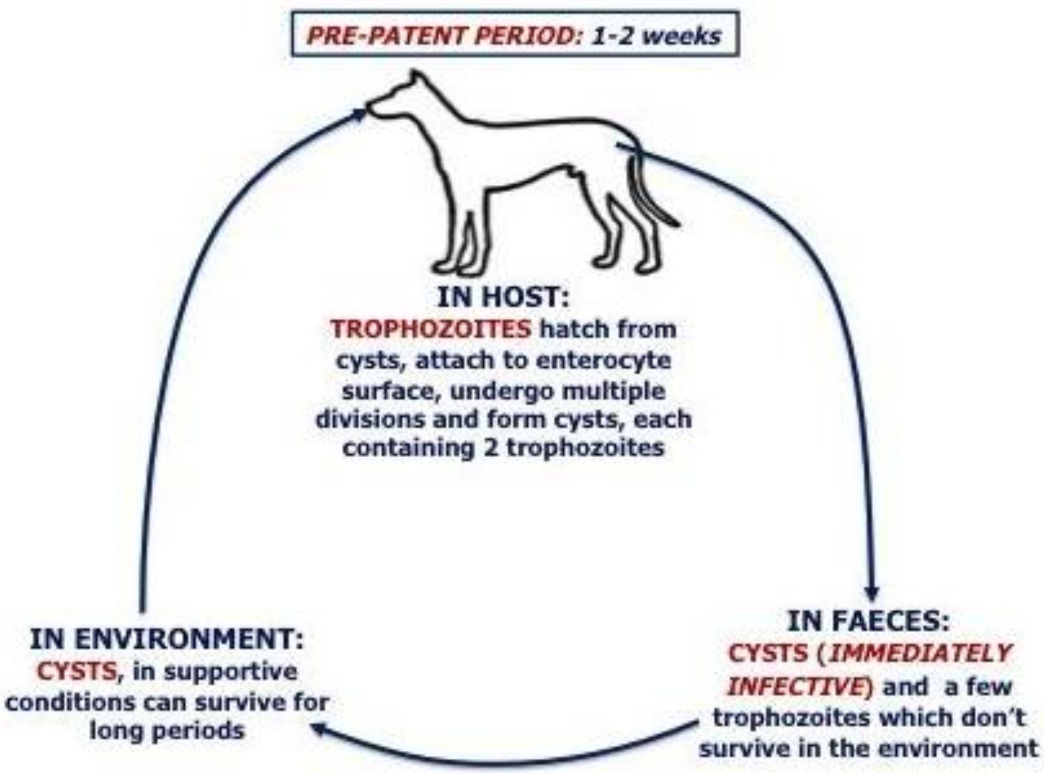

Figure 3. Life cycle of *Giardia* species in animals (Villeneuve *et al*., 2015).

In the small intestine's enterocytes, *Cystoisospora* species reproduce asexually (merogony) and later sexually (gametogony and fertilization) (Figure 4). The infectious stage is the sporulated oocyst, which releases eight sporozoites when it hatches after being consumed by an appropriate host. After entering enterocytes, these sporozoites quickly split to create merozoites that are encased in a meront and can take up the majority of the host cell. Depending on the species of *Cystoisospora*, a meront can contain up to several thousand merozoites. The meronts are released into the intestinal lumen by the ruptured infected cell at the completion of merogony, where they infiltrate fresh enterocytes. The merogony cycle can be repeated multiple times, depending on the species, which significantly increases the number of parasites and the number of host cells that are infected and injured (Dubey, 2009).

Merozoites that enter host cells eventually develop into microgametocytes (also known as "male") and macrogametocytes (also known as "female") inside the enterocytes rather than dividing to make meronts. While each macrogametocyte has a single macrogamete, each microgametocyte has many microgametes. The microgametes are then released when the microgametocyte breaks down, fertilizing the macrogametocytes to generate gamonts that eventually mature into unsporulated oocysts. These oocysts are expelled in faeces after rupturing from the enterocytes into the intestinal lumen. Under favourable conditions, the oocysts sporulate in the environment over a few days and become infectious. By consuming sporulated oocysts, dogs or cats can get infected (Dubey, 1978).

Dogs and cats may shed oocysts for two to four weeks, while *Cystoisospora* species have a pre-patent period of one to two weeks. Different parasite species have different life cycle phases in the small and large intestines. When paratenic hosts, typically small mammals, consume sporulated oocysts of *Cystoisospora* species, the sporozoites that are released break through the intestinal wall and encyst intracellularly as single bradyzoites. Numerous tissues and organs, but especially the lymph nodes in the mesentery, contain the cysts. Dogs and cats can contract patent infections by consuming contaminated paratenic animals (Dubey, 2009).

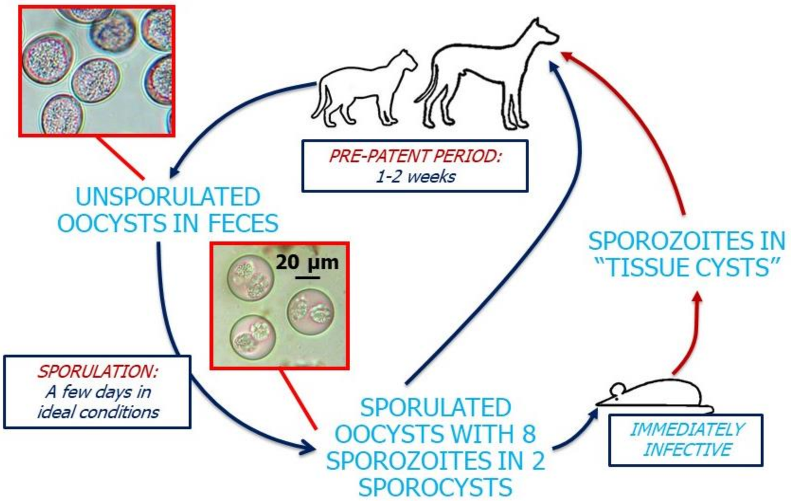

Figure 4. Life cycle of *Isospora* species (Dubey, 2009).

Table 11. Life cycle of common gastrointestinal protozoa in dogs and cats.

Protozoan	Definitive Host(s)	Site in Host	Transmission Route	Infective Stage	Lifecycle Type	Zoonotic Potential
Giardia spp.	Dogs, cats, humans	Small intestine	Fecal-oral, contaminated water	Cyst	Direct	Yes (*Giardia duodenalis*)
Cystoisospora spp. (e.g. *C. canis*, *C. felis*)	Dogs (*C. canis*), cats (*C. felis*)	Small intestine	Ingestion of sporulated oocyst	Sporulated oocyst	Direct	No
Cryptosporidium spp.	Dogs, cats, humans	Small intestine (microvillus border)	Fecal-oral, waterborne	Sporulated oocyst	Direct	Yes (*C. parvum*, *C. felis*)
Tritrichomonas foetus	Cats (mainly young cats/kittens)	Large intestine (colon)	Direct contact (grooming, shared litter)	Trophozoite (no cyst stage)	Direct	Rare
Toxoplasma gondii	Cats (only definitive host)	Intestinal epithelium (sexual), tissues (asexual)	Ingestion of tissue cysts or sporulated oocysts	Sporulated oocyst or tissue cyst	Indirect	Yes
Neospora caninum	Dogs (definitive host), cattle (intermediate host)	Intestine (dogs); tissues (others)	Ingestion of tissue cysts or oocysts	Sporulated oocyst	Indirect	No (but affects livestock)
Sarcocystis spp.	Dogs, cats (definitive hosts)	Intestine	Ingestion of muscle tissue from intermediate host	Sporulated oocyst or sarcocyst	Indirect	Rarely (some species)

Source: ESCCAP (2004).

2.4.3. Clinical manifestations

Giardia infections can cause severe enteritis in animals, which can lead to diarrhea and dehydration. Both the parasite's direct action and the body's reaction to it cause pathology and clinical symptoms (Kirkpatrick, 1987). When symptoms do appear, they are associated with malabsorption and poor digestion (Barr, 2006). Apoptosis of epithelial cells, barrier and transport failure, and inhibition of lipases and disaccharidases are some of the hypothesized processes (Troeger *et al*., 2006). Villar and microvillar blunting brought on by the host's inflammatory response reduces the surface area for absorption. These microscopic alterations lead to clinical symptoms such as steatorrhea, malodorous diarrhea, and weight loss or inability to gain weight. Appetite may be normal (Barr, 2006).

Infections with *Isospora* spp. typically exclusively cause illness in puppies and kittens. Puppies and kittens which are clinically unwell may have watery diarrhea, occasionally with blood in it, vomiting, and abdominal pain. Death and severe dehydration may result, depending on the animal's age and parasite burden (Lappin, 2010).

2.5. Zoonotic impacts of gastrointestinal parasites of dog and cat

Numerous gastrointestinal parasitic zoonoses, such as ancylostomiasis, toxocariasis, giardiasis, toxoplasmosis, cryptosporidiosis, and echinococcosis, are found in dogs and cats (Smith *et al.*, 2009). The intestinal helminths that pose the greatest threat to public health are toxocara and hookworm species in dogs and cats. Eosinophilic enteritis or cutaneous larva migrans are the two main symptoms of hookworm infection in humans (Bouchaud *et al*., 2001). However, three clinical syndromes, visceral larva migrans, ocular larva migrans, and covert toxocariasis, have been linked to human *Toxocara* infection (Taylor and Holland, 2001). Dog faeces have been identified as a major public health concern globally, particularly in developing nations and socioeconomically disadvantaged communities, because they contain infectious parasitic forms (larvae, eggs, helminth cysts, and protozoan oocysts) that can contaminate the environment and pose a high risk of infection for humans (Soriano *et al*., 2010).

Dogs and cats tend to excrete helminth eggs or larvae with their faeces into the environment that are transmittable to the human population. The transmission of these zoonotic agents might happen through direct contact with sick animals, contaminated water and food, or indirect contact with animal faeces, as the majority of these parasites have an oral-faecal transmission cycle (Martínez-Moreno *et al*., 2007). The potential role of companion animals as disease reservoirs has been identified as a major public health concern in urban environments in contrast to rural ones (Traub *et al*., 2005).

The hazards of disease transmission may be increased by inadequate veterinary care, zoonotic awareness, overcrowding, and poor hygiene. Furthermore, in areas where raising livestock is economically significant, intimate contact between humans, dogs, and cats is a natural aspect of life. Many people believe that dogs and cats are devoted companions and close friends of people. Humans are exposed to zoonotic agents due to increased contact between domestic animals and people brought on by the growing number of companion animals (Lorenzini *et al.*, 2007).

2.6. Diagnosis of gastrointestinal parasites of dogs and cats

There are more laboratory tests available to diagnose disorders of the gastrointestinal tract in cats and dogs. Faecal examination is still one of the most crucial diagnostic techniques in the study of gastrointestinal issues, and the use of these tests can result in quicker and more accurate diagnosis. Examination of direct smears of faeces may readily identify ova, oocysts, larvae, or trophozoites of some nematode and protozoal parasites (Figures 5 and 6) (Lappin and Calpin, 1998). The motility of trophozoites assists their identification in faecal smears and can aid in the diagnosis of protozoal disorders such as giardiasis and trichomoniasis. The primary limitations of faecal smear examinations are small sample size, and the method does not concentrate parasites. An infection cannot be ruled out by a negative result (Pitts *et al.*, 1993).

Ova of nematode parasites and the cysts and oocysts of most protozoa are easier to find if these forms of the organisms are concentrated using various flotation methods. Zinc sulphate, sodium chloride and sugar solutions are common solutions used for routine screening flotation tests, and each of these solutions has advantages and disadvantages over the others (Zajac *et al.*, 2002). Zinc sulphate faecal flotation is an excellent routine screening technique for helminth and protozoal infections, including giardiasis (Matz and Guilford, 2003).

Using faecal immunodiagnostic tests, the enzyme-linked immunosorbent test (ELISA) can be used as a diagnostic tool for *Giardia* and *Cryptosporidium* species. and fluorescent antibody tests of trophozoite antigens, or cysts and oocysts, respectively (Knisley *et al.*, 1989). Only a small amount of information is available about the sensitivity and specificity of these assays in dogs and cats. One study showed the faecal ELISA test for *Giardia* spp. to be less sensitive and to have a lower relative specificity than the zinc sulphate flotation technique (Payne *et al.*, 2002).

Microscopy's inherent drawbacks include its lack of species differentiation and limited or inconsistent sensitivity. As an alternative, DNA amplification techniques for molecular diagnostics have demonstrated improved sensitivity and specificity, providing multiplex formats and enabling additional genotype analysis (Fitri *et al*., 2022). The technology known as polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) was created to enable the direct detection and identification of canine hookworm eggs from faeces that are morphologically identical (Traub *et al*., 2004). More specialized testing, like PCR, is needed for a definitive *Toxocara* identification. Because there are either few or just juvenile worms present, certain infections may go unnoticed. On the other hand, coprophagy in dogs may result in false-positive test results (TroCCAP, 2019). According to Scheuer (1987), the ELISA test, which uses TES antigens, is a sensitive method for figuring out whether or not a bitch is carrying somatic larvae.

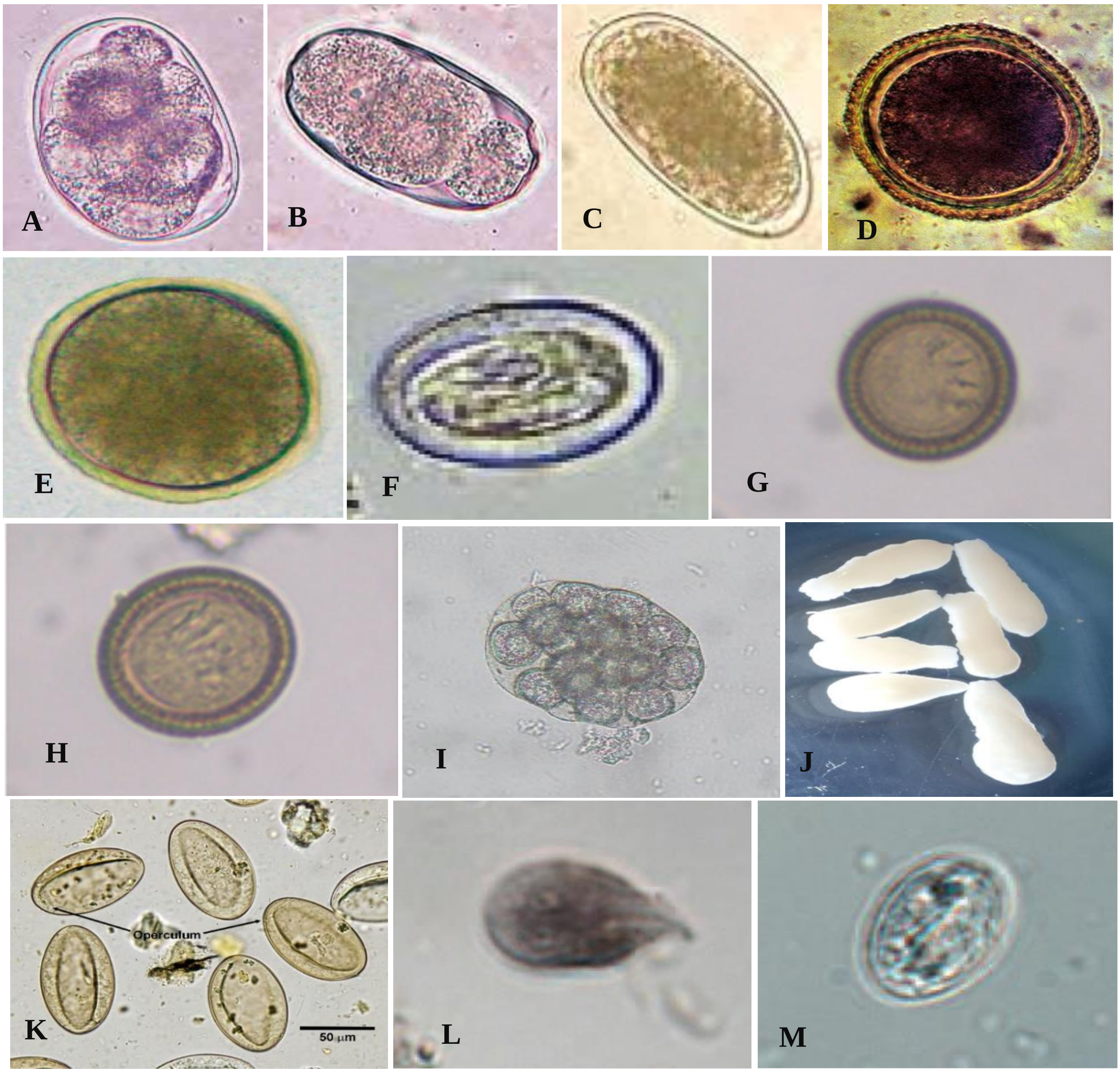

Figure 5. Egg of *Ancylostoma caninum* (A), thin-shelled oval egg of *Ancylostoma tubaeforme* (B) (Byron, 2003). *Ancylostoma* spp. egg (40x) from a cat faecal sample (C) (Hussam, 2015). An egg of *Toxocara canis* with a pitted surface on faecal flotation (D). *Toxocara cati* egg; observe the black colour and pitted shell (E) (TroCCAP, 2019). Embryonated eggs of *Physaloptera* sp. (F) (Fernando *et al*., 2019). *Taenia* spp. (G and H) mature eggs with a thick embryophore, a distinct oncosphere, and parallel-aligned hook pairs (Cristian *et al*., 2018). *Dipylidium caninum* egg packet (160x) (I) and Cucumber seed-shaped gravid *D. caninum* proglottids recovered from the faeces of an infected animal (J). *Diphyllobothrium* eggs are oval, have a thin, smooth shell, and have an operculum (lid) at one end. They measure roughly 65 to 70 µm by 40 to 50 µm. Frequently, there is a tiny protuberance at the other end. (K) (Conboy, 2009). *Giardia trophozoite* (L) and *Giardia* cyst (M) (Carlin *et al*., 2006).

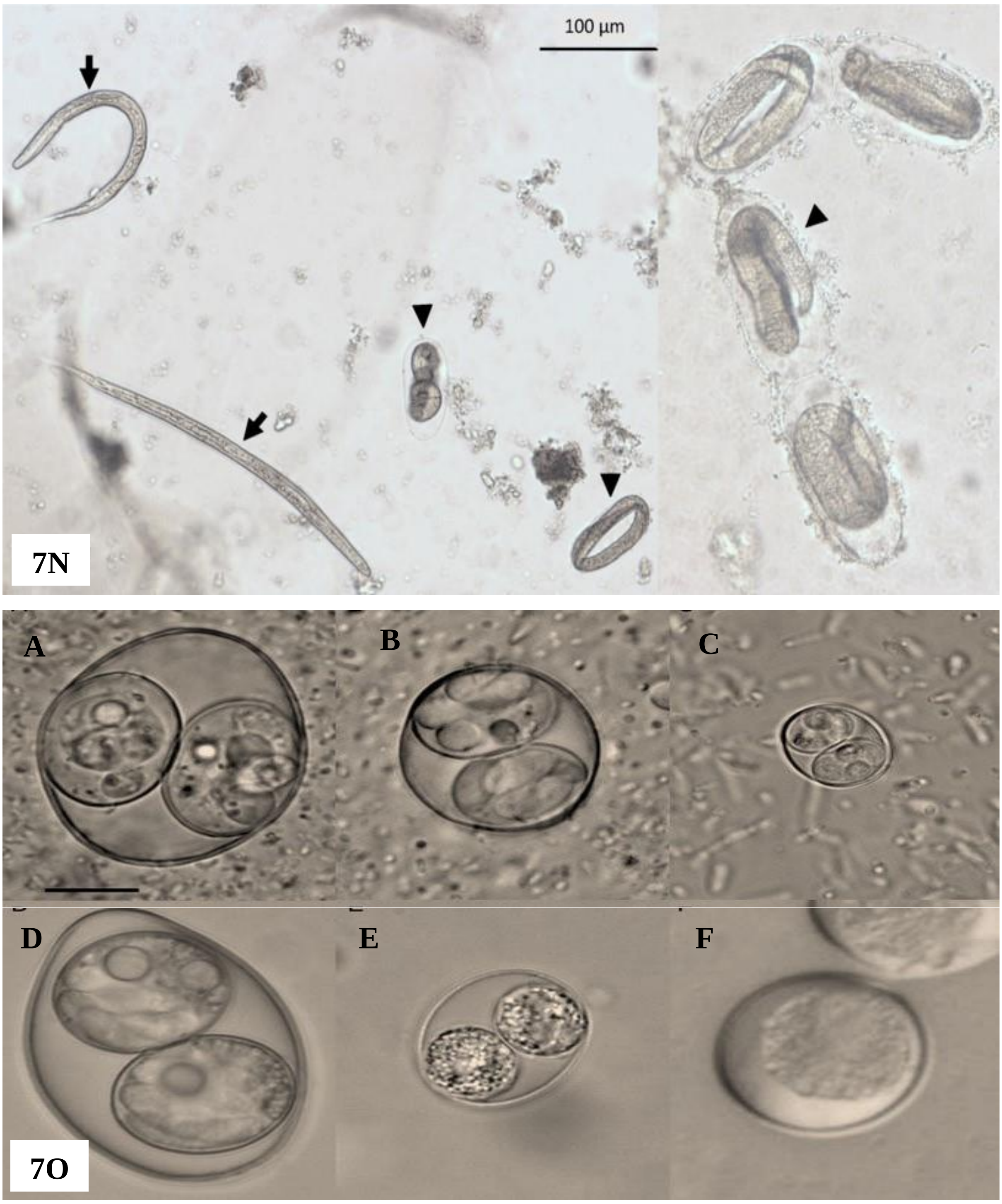

Figure 6. By using the zinc sulphate flotation technique (7N), *Strongyloides stercoralis* first-stage larvae (arrows) and larvated eggs (arrowheads) were separated from dog faeces (Walter *et al*., 2018). Some tissue coccidia have sporulated oocysts, including the dog parasite *Hammondia heydorni* (C), the cat parasite *Cystoisospora* species (D, *C. felis*; F, unsporulated *C. rivolta*), the pig parasite *C. suis* (E), and the dog parasite *Cystoisospora* species (A, *C. canis*, B, *C. ohioensis*), scale bar represents 10 µm (7O) (Mosun *et al*., 2016).

2.7. Control of gastrointestinal parasites of dogs and cats

The effects that intestinal parasites can have on a pet's health vary greatly depending on a variety of factors; however, puppies and kittens are particularly susceptible to developing serious problems associated with intestinal parasites. And while a wide range of treatment options and preventatives are available, intestinal parasites remain prevalent in both cats and dogs (Blagburn, 2001).

Historically, early and efficient deworming of puppies and kittens has been the main focus of attempts to manage gastrointestinal helminths in dogs and cats. Currently, the American Association of Veterinary Parasitologists and the Centers for Disease Control and Prevention jointly recommend that kittens, which do not contract gastrointestinal helminth infections until after birth, be dewormed at 3, 5, 7, and 9 weeks of age, and that pups be dewormed at 2, 4, 6, and 8 weeks of age using an anthelmintic effective against both ascarids and hookworms. Deworming nursing dams and their offspring is recommended. At the earliest age feasible (6 to 8 weeks), all pets should start taking a monthly heartworm preventive that also manages intestinal parasites. They should also have regular faecal tests and receive treatment as necessary (Little, 2005).

Frequent parasite treatment also reduces environmental contamination with infectious stages, which lowers the risk of zoonotic exposure and transmission. Puppies should receive special attention when it comes to intestinal parasite treatment. Deworming should start as early as two weeks of age and be repeated every two weeks until regular monthly treatment is started using intestinal parasite-effective solutions (Villeneuve *et al.*, 2015).

To assess adherence to preventive use, track the effectiveness of products, and screen for infection with a variety of internal parasites, routine faecal examination is beneficial. Puppies benefit from multiple faecal tests during their first year of life since they are more likely to have parasites. Young, adult, and elderly dogs and cats should all have their faecal samples screened for intestinal parasites at least once a year; however, depending on the usage of preventive measures and the overall risk assessment based on lifestyle, more frequent testing may be necessary (Neves *et al*., 2014).

To prevent re-infection, it is important to scoop the litter box and clean up the yard after each and every bowel movement. Since tapeworms are often spread from fleas, topical year-round flea preventative is also recommended. Importantly owners should remember keeping their own good hygiene and wash hands after handling their animals. Overall, practicing good basic hygiene is important in minimizing intestinal parasites' zoonotic potential. These include, in particular, frequent hand washing, cleaning fruits and vegetables before eating them, cleaning up pet waste from the yard and during dog walks right away, covering sandboxes when not in use, keeping dogs and cats from wandering, and keeping an eye on small children to avoid geophagia (soil consumption) (Little, 2005).

Many diseases that affect animal species of veterinary interest can be effectively prevented by vaccination (Unnikrishnan *et al*., 2012). Vaccines have a transcendental effect on parasitic disease control. They require the approval of the appropriate authorities, just like any other remedy (Heldens *et al*., 2008). However, certain vaccines' exorbitant prices limit their potential for commercialization. Few vaccines show promise for eventual commercialization despite advancements in experimental vaccination development (Schetters, 1995). Legislative changes are anticipated to offer financial support for the production and distribution of commercial deworming vaccinations, which are used to combat gastrointestinal parasites (Schetters and Gravendyck, 2006). In general, vaccination is acknowledged as one of the most practical and efficient methods of managing gastrointestinal parasite infections, even in the face of global scientific advancements. However, for both scientific and financial reasons, the creation of vaccinations to prevent these parasites has proven to be extremely challenging (Versteeg *et al*., 2019).

3. MATERIALS AND METHODS

3.1. Study areas

Ethiopia is one of the populous landlocked nations in East Africa. Administratively, Ethiopia is divided into regional states and city administrations (Country of Origin Information, 2020). The zones that make up the regional administrations are divided into districts (woredas) and subsequently into sub-districts (kebeles), each of which has an average population density of 5,000 people (Deribe, 2015). This study was conducted in Bishoftu, Dukem, Addis Ababa and Sheno in Central Ethiopia (Figure 8). The four districts/areas were chosen from a list of Central Ethiopian districts that were easily accessible. They represent two distinct agroecological areas: a midland area (Bishoftu and Dukem) at 1500-2000 m above sea level (masl) and a highland area (Addis Ababa and Sheno) at elevations above 2000 masl (MOA, 1998; PECA, 2013).

Bishoftu town, the initial study location, lies 45 kilometres southeast of Addis Ababa, Ethiopia. The town, which has an average elevation of 1850 masl, is situated at 9° N and 40° E in the Ada'a district of the East Shewa zone of Oromia Regional State. Rainfall in the area is bimodal and totals 866 mm annually. With an average relative humidity of 61.3%, the region has typical annual maximum and lowest temperatures of 26°C and 14°C, respectively. There are 127,678 residents in the town (CSA, 2015). Additionally, several resorts are frequented by non-residents due to the town's proximity to numerous picturesque lakes. There are an estimated 4188 dogs (Tegegne and Ayehu, 2022), compared to 160,697 cattle, 22,181 sheep, 37,510 goats, 1660 horses, and 191,380 poultry (Bachewe, 2009).

Dukem, the second study location, is located adjacent to the main road to Adama, 37 kilometres southeast of Addis Ababa. Between latitudes 8045'25" N and 8050'30" N and longitudes 38051'55" E and 38056'5" E, the study area physically covers 9,630.6 hectares. It is 1950 masl. The towns of Bishoftu in the southeast and Gelan in the majority of the north, respectively, about the town. The remaining eastern and western parts of the town are bounded by four neighbouring Peasant Associations of the Akaki district (OUPI, 2017). It is estimated that Dukem is home to 944 dogs (Tegegne and Ayehu, 2022).

The third study area, Addis Ababa, is located on the western border of the Rift Valley and in the central highlands of Ethiopia (CSA, 2007). It is located at an elevation of 2408 masl and at latitudes 90 3' North and 380 43' East. The average annual rainfall is 1201 mm, and the average lowest and highest temperatures are 9.4^0C and 23.2^0C, respectively. The rainfall pattern is bimodal, with the months of February through April seeing the smallest showers and June through September seeing the longest and heaviest rainfall (Tegegne *et al*., 2000). It is estimated that there are between 250,000 and 350,000 dogs in Addis Ababa, with half of them being owned (Abraham *et al*., 2010).

Sheno, the fourth study area, is situated 78 kilometres from Addis Ababa, the capital, in the Oromia Regional State's North Showa Zone. Sheno is located between 1950 and 2918 masl at 9°20'N latitude and 39°18'E longitude. The terrain is flat and the agro-ecology is highlands. Bimodal rainfall patterns with unpredictable distribution are what define the region. Rainfall averages 1366.7 mm per year. The average yearly temperature is 12.9°C at the lowest point and 19.9°C at the highest point. The population's primary source of income is agriculture (CSA, 2012). The area's livestock population includes 1.51 million cattle, 1 million sheep, 223,245 goats, donkeys, horses, and mules, with corresponding numbers of 254,553, 107,368 and 3,739, while dogs are estimated to number 4188 (CSA[1], 2012).

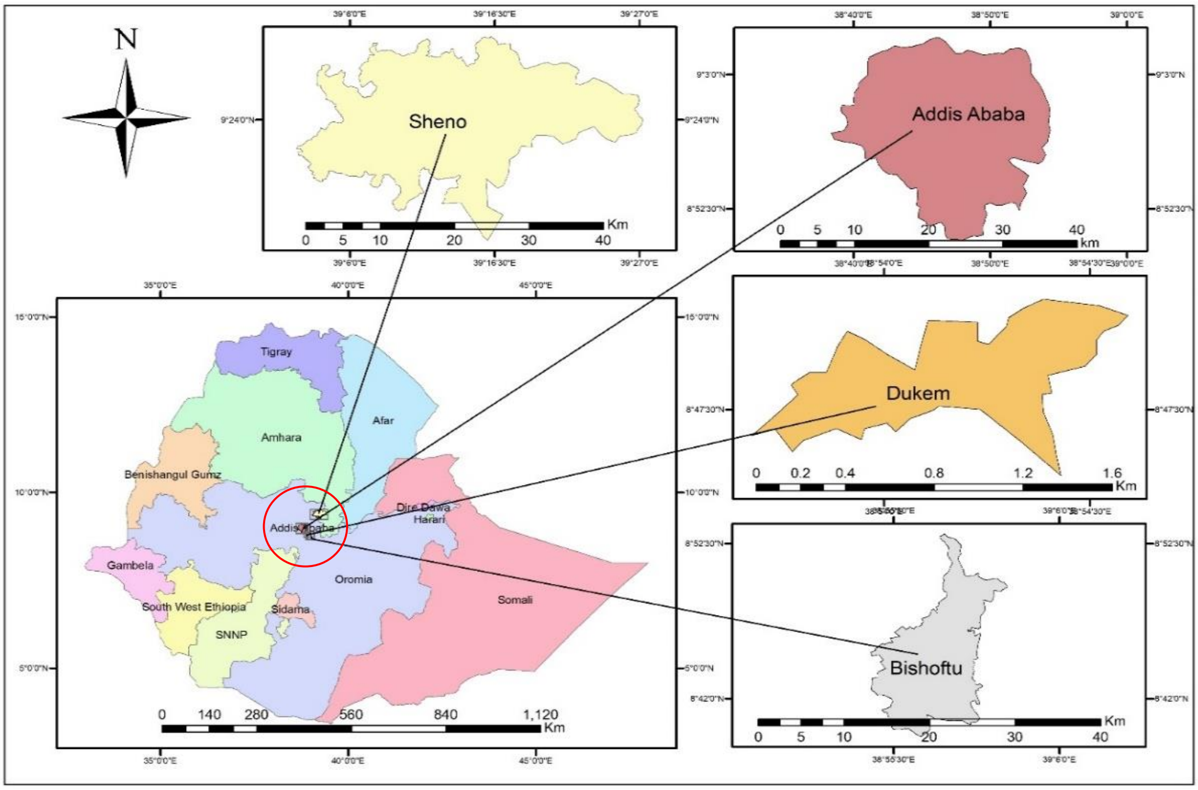

Figure 7. Map of Ethiopia showing location of the study area, ArcGIS 10.8.2.

3.2. Study design and study population

A cross-sectional study was conducted from February, 2022 to April, 2023 in Bishoftu, Dukem, Addis Ababa and Sheno areas (Figure 8) in Central Ethiopia to investigate the epidemiology of dog and cat gastrointestinal parasites and evaluate the community's degree of awareness, attitudes, and practices about these parasites in the selected Central Ethiopian areas. Privately owned dogs and cats of both sexes, as well as their owners, comprised the study population.

3.3. Sample size and Sampling technique

The formula for random sampling provided by Thrusfield (2005) was used to determine the sample size. The sample size for dog gastrointestinal parasites was determined using an expected prevalence rate of 59.2% as recorded by Mitiku *et al*. (2020). Regarding gastrointestinal parasites of cats, the sample size was determined at an expected prevalence of 50%, as there were no data concerning the prevalence of gastrointestinal parasites in the study areas, with a 95% confidence interval and 5% absolute precision. Accordingly, the sample size was calculated as follows.

$$n = \frac{1.96^2 \, Pexp\,(1-Pexp)}{d^2}$$

Where:
n = desired sample size,
Pexp = expected prevalence, and
d = 0.05

Based on the calculation, 371 dogs were expected to be included in the study, but purposively to increase the precision of the study outcome, 701 dogs were considered for faecal and data collection in this study. A post-mortem examination was conducted on thirteen dead dogs to detect any adult gastrointestinal parasites. Regarding cat sample size, 384 cats were expected to be included in this study based on the above sample size determination formula, but due to budget and resource constraints, lack of animal owners' full cooperation during sample collection, due to lower population of cats, absence of these animals at home during sample collection and aggressive nature of these animals during sample collection, 213 cats were included for faecal sample collection. Therefore, totally 914 animals (701 dogs and 213 cats) were sampled and examined in this study.

A simple random sampling procedure was employed stage by stage (multi-stage) for faecal and data collection in the study areas. First, 'Kebeles' were randomly picked by the lottery system from each town/city to be considered for sample collection. Then households within the considered 'Kebeles' that had dog or/and cat were identified, and sticky marks/notes (indicating the presence of dog or/and cat and house number) were placed on the exterior door or fence of homes before data and sample collection. Then, households were selected randomly for data and faecal sample collection.

Thus, from Bishoftu, five 'Kebeles' were randomly picked by a lottery system to be considered for sample collection. Then, households within the considered 'Kebeles' that had dog or/and cat were candidates for random sample collection. Based on this, 408 (305 dogs and 103 cats) animals were considered from Bishoftu town in this study. Similarly, from Dukem town and Sheno town, three 'Kebeles' for each were taken into account for sampling, and 190 dogs and cats from Dukem town and 127 dogs from Sheno town were sampled in this study. From Addis Ababa, Gullele sub city Woreda/district 04 was considered, and four 'Kebeles' of the district were selected for simple random sample collection and households that had dog and/or cat within the considered 'Kebeles' were considered for sample collection. Thus, 134 dogs and 55 cats were sampled from this specific study area.

3.4. Faecal sample collection

Faecal samples were collected with the permission and assistance of the dog and cat owners. Approximately 5-10 grams of faecal sample from each study animal was collected either directly from the rectum of the animals or from the top layer of recently voided faeces using a disposable glove (Pereira *et al*., 2017; Teshager *et al*., 2023). Then, the collected faecal samples were placed in labelled clean plastic containers (universal bottles) and preserved in 10% formalin, then transported in an icebox to the College of Veterinary Medicine and Agriculture of Addis Ababa University parasitology laboratory for further processing on the same day of collection. Samples left unprocessed on the same day were examined on the following days. At the time of sampling, the study site, animal breed, sex, age, feeding condition, housing condition, and their faecal consistency were recorded on a data recording format (Appendix 1). The faecal consistency was determined by physical observation of the faeces during sample collection. Cats aged from 6 months up to 1 year old were considered as young cats, whereas cats with the age of greater than 1 year old were considered as old cats.

Dogs with the age less than 6 months, 6 months up to 1 year, and greater than 1 year were considered as puppy, young and adult dogs, respectively (Bone, 1998).

3.5. Parasitological procedures

Faecal samples were inspected macroscopically and microscopically. Sampled faeces were initially examined macroscopically or grossly for the presence of any adult gastrointestinal parasite or segments of cestodes, and the detected parasites were identified based on the keys provided by Zajac and Conboy, (2012), and the results were recorded appropriately (Appendix 2). Then, samples were microscopically examined in search of gastrointestinal parasite eggs, cysts and oocysts using faecal centrifugal-flotation technique and McMaster technique. Post-mortem examination was conducted on dead dogs to detect any adult gastrointestinal parasites in their gastrointestinal tracts.

3.5.1. Floatation technique

Faecal samples were examined using the centrifuge-flotation technique in saturated zinc sulphate solution (specific gravity=1.20) to detect gastrointestinal parasites' eggs, cysts and oocysts (Soulsby, 1982). Accordingly, about three grams of the faecal sample was measured and added to mortar, then 10 ml of floatation fluid (zinc sulphate solution) was added to the faecal sample contained in mortar then it was crushed well with pestle and mixed thoroughly. The solution was sieved into a beaker using a tea strainer to remove rough materials. The filtrate was added to the centrifuge tube and centrifuged at 3000 rpm for 3 minutes, then a top-up of the floatation fluid was added until a cone shape was formed at the top of the centrifuge tube, then coverslip was placed on the top of the tube and allowed to stand for 15-20 minutes. The coverslip was raised up gently and placed on the microscopic slide, and examined under the microscope (Soulsby, 1982; Lorenzini *et al*., 2007).

The entire slide was examined under the microscope, and parasite eggs, trophozoites, cysts and oocysts were identified by using a 10x objective lens followed by 40x objective magnification of compound microscope. Iodine solution was used to facilitate protozoan and cyst identification. Using ova/cysts/oocysts identification keys, morphologically parasites were identified to the level of genera or species based on the keys provided by Hendrix (2003) and Zajac and Conboy (2012). The sample was considered as positive when at least one type of parasite egg/cyst/oocyst was detected (MAFF, 1986). Then, faecal samples positive for ova of helminths and cyst/oocyst of protozoa using the flotation technique were re-analysed using the McMaster technique. McMaster chambers were filled with the faecal suspension using a pipette, and floating parasitic elements were counted and the number of eggs per gram (EPG) was calculated and recorded.

3.5.2. McMaster egg counting technique

McMaster chambers were filled with the faecal suspensions using a pipette mixed with a saturated zinc sulphate solution, and after 5 minutes, floating parasitic elements were counted. The number of eggs/cysts/oocysts per gram of faeces was calculated based on Taylor *et al.* (2007) as follows: three grams of faeces were mixed in a clean glass beaker with 42 ml of flotation solution (zinc sulphate solution) until the mixture is homogeneous, the mixture filtered with a sieve and the filtrate collected in a new beaker. The filtrate was taken with a pipette to fill both chambers of the McMaster slide and let the slide stand for 5 minutes to allow parasite eggs/cysts/oocysts to float to the surface. Then all eggs/cysts/oocysts inside of the grid areas of both chambers were counted under the microscope. Then, the total eggs/cysts/oocysts per gram (EPG) of faeces was calculated. The total number of eggs/cysts/oocysts of the two chambers was multiplied by 50. This gives the EPG of faeces. Then, based on Taylor *et al*. (2016), three groups were categorized based on the EPG scores (intensity of infection): mild (EPG $< 1,000$), moderate (EPG $\leq 10,000$), and severe (EPG $\geq 10,000$).

3.5.3. Postmortem examination

Dogs that died shortly before or after receiving medical care at the Veterinary Teaching Hospital of the College of Veterinary Medicine and Agriculture of Addis Ababa University, as well as recently dead dogs from the surrounding areas of the college, were subjected to postmortem examinations. The dogs were necropsically examined for the presence of any adult gastrointestinal tract helminths. The entire alimentary tract was removed in the college's post-mortem facility, and the small and large intestines, stomach, and esophagus were all securely ligated with gauze. The entire intestinal tract was then isolated from the other gastrointestinal tract segments and divided into the small and large intestines. After being exposed, the intestines were cut lengthwise and examined visually. The heads of any tapeworms and other adult parasites were meticulously examined for attachment (Reid, 1962). After being repeatedly cleaned in normal saline, the parasites that were found were stored in glycerine alcohol-filled containers for additional analysis (Soulby, 1982). The keys and descriptions of Anderson (1992) and Khalil *et al*. (1994) were used to identify intestinal helminths. To make sure the environment wasn't contaminated, the carcasses were burned in the disposal field of the college.

3.6. Questionnaire survey

3.6.1. Participant identification and Data collection

A structured questionnaire interview survey was conducted in Bishoftu, Dukem and Addis Ababa to assess the knowledge, attitude and practices (KAP) of dog and cat owners toward dog and cat gastrointestinal parasites and related zoonosis. Participants who only had either a dog or a cat were included in the survey. The survey included respondents (households) who were equal to or above eighteen years of age. A formula provided by Arsham (2002), $N=0.25/SE^2$, where N is the sample size and SE is the standard error, was used to determine the number of households that were included in the questionnaire survey. A standard error of 0.035 was used. Although $N=0.25/(0.035)^2 = 204$, the survey comprised 272 households in total. The 272 respondents (172 dog owners and 100 cat owners) were chosen using a simple random sampling technique.

The selected respondents were asked for their permission to participate and answer all questions of the survey. The questionnaire (Appendix 3) was developed originally in English, and it was translated into Amharic and Afan Oromo and administered by data collectors. After being used in both Amharic and Afan Oromo, the questionnaire was translated back into English to document the information gathered. Four components made up the survey's questionnaire. The first section focused on questions about the sociodemographic information of animal owners, including age, education level, gender, occupation, length of pet ownership, and reason for keeping the pet.

Questions about the owner's general knowledge were the main emphasis of the second section, whether or not they: know what gastrointestinal parasites are, know that dogs/cats can have gastrointestinal parasites, know any clinical sign of gastrointestinal parasites infection in dogs and cats, know the mode of transmission of gastrointestinal parasites from animal to animal, know how to control/prevent gastrointestinal parasites in dogs and cats, know any gastrointestinal parasites of dogs and cats that can be transmitted to humans and know the mode of transmission of gastrointestinal parasites from pet to man.

The third section focused on questions that were related to the owner’s general attitude about gastrointestinal parasites of dog and cat as whether or not they: think gastrointestinal parasitosis as a serious disease, think the health risk of pet ownership, think the risk of getting gastrointestinal parasitosis by playing with dog/cat, think feeding raw food to dog and cat can cause gastrointestinal parasitosis, think washing hands with water and soap hinder the transmission of gastrointestinal parasites to humans, think medication/treatment is necessary when dog and cat experience gastrointestinal parasitosis and think health education can reduce gastrointestinal parasite prevalence.

The fourth section focused on questions that were related to the owner’s management and practices about pet gastrointestinal parasites. The following are the points included in this section: issues of animals housing condition, feeding condition, usual place of defecation of dog and cat, cleaning and disposing dog and cat excrement, having access to any veterinary service for dog and cat, using protective equipment during animal house/environment cleaning, having usual contact with dog and cat, eating raw meat/vegetable and washing hand before meal.

3.6.2. Determining KAP scores

There are two types of questions to measure the level of KAP of animal owners regarding gastrointestinal parasites of dog and cat, with some questions having one (“yes” or “no” answer) or more possible answers, which were given one point for a correct response and zero point for the incorrect one. The other type of questions had open-ended answers, representing poor (zero point) and good (one point) levels of KAP. A higher score indicated a greater understanding of gastrointestinal parasites in dogs and cats. The overall knowledge score varied from 0% to 100%. The cut-off value for the KAP score level was determined by the participant's capacity to explain gastrointestinal intestinal parasites, knowing clinical signs, mode of transmission, control and prevention of these parasites in dogs/cats, appropriate management and practices, and level of their attitude towards gastrointestinal parasites of their dog/cat. The questionnaire consisted of 26 questions in total, and an average KAP score of 50% or higher was deemed to indicate "good knowledge," which denotes adequate understanding of gastrointestinal parasites in cats and dogs. Conversely, "poor knowledge," which denotes inadequate knowledge, was defined as having an average KAP score of less than 50%. Similarly, "positive attitude," "negative attitude," "good practice," and "bad/poor practice" were categorized using a comparable scoring method that was modified from Memon *et al*. (2015) and Birhanu (2021).

3.7. Data management and Statistical analysis

3.7.1. Methods of data analysis

The gathered data were entered into a Microsoft Excel sheet 2010. Statistical Package for Social Sciences (IBM SPSS version 27) was used to analyze the data. The existence or lack of at least one gastrointestinal parasite in every faecal sample was the main variable. An animal was labelled as positive if it tested positive for at least one species of parasite, and preliminary univariate logistic regression analysis was performed considering the following independent variables (risk factors): study site, sex, age, feeding condition, housing condition, faecal consistency, and agro-ecology. By dividing the number of dogs and cats with gastrointestinal parasites by the total number of dogs and cats examined, the prevalence was determined. Descriptive statistics, frequencies, and percentages were calculated, and the Pearson chi-square ($\chi 2$) test was used to detect possible associations between parasitic infection (with helminths and protozoan parasites) and different risk factors (study site, sex, age, feeding condition, housing condition and agro-ecology). Through multivariable logistic regression analysis, the impact of each independent variable (risk factors) on the outcome variable (positivity of gastrointestinal parasites in dogs and cats) was evaluated after adjusting each independent variable for all other variables and confounding factors. The degree of association between various exposure variables (risk factors) and the outcome variable (prevalence of gastrointestinal parasites) was assessed using the adjusted odds ratio and associated confidence interval. Odds ratio and confidence interval of each risk factor were calculated using the category with the lowest prevalence as a baseline of comparison using logistic regression. For analysis of continuous data (faecal egg count or egg per gram of faeces (epg)), ANOVA was used to compare means (epg) of three or more groups of parasites.

Regarding the analysis of knowledge, attitude and practices (KAP) of pet owners toward gastrointestinal parasites of their dog and cat, descriptive analysis was used to determine the frequencies and percentage of different variables of socio-demographic characteristics of dog and cat owners, pet ownership, and purpose for keeping their pet. After calculating the average KAP score for knowledge, attitude, and practices from the total scores, the results were evaluated. For every independent variable (socio-demographic factors), the mean knowledge, mean attitude, and mean practices were determined together with their corresponding standard deviations. Only possible predictors with a p-value less than 0.25 were taken into consideration for the multivariate analysis to assess the level of animal owners' awareness regarding gastrointestinal parasites of dogs and cats. Bivariate analysis was used to evaluate the relationship between each independent variable and the dependent variables. When the p-value was less than 0.05, it was deemed statistically significant.

3.7.2. Data quality control

Data and sample collection and laboratory investigations were conducted with data quality control mechanisms in place. All data collectors received the necessary orientation regarding the goals of the study. Corrective action was taken immediately after an error was discovered during the pre-, analytical, and post-analytical phases. Therefore, every day, the data and samples collected in the field and laboratory analysis and results were checked, recorded, and interpreted appropriately. Faecal samples were taken from dogs and cats using the appropriate procedure by including all the necessary information on the data recording sheets. All faecal samples were processed using the standard parasitological laboratory procedures. Similarly, postmortem examination was also conducted according to standard procedures and all obtained results were recorded appropriately.

3.8. Study variables

List of dependent variables for community-based questionnaire interview survey:

- ✓ Knowledge of dog and cat owners about gastrointestinal parasites of dogs and cats.
- ✓ Attitude of dog and cat owners toward gastrointestinal parasites of dog and cat.
- ✓ Practices of dog and cat owners related to gastrointestinal parasites of dogs and cats.

List of independent variables for community-based questionnaire interview survey:

- ✓ Districts, age, sex, education level, and occupation of dog and cat owners.

List of dependent variables for the prevalence study of gastrointestinal parasites in dogs and cats:

- ✓ Faecal positivity for gastrointestinal parasites of dog and faecal consistency.
- ✓ Faecal positivity for gastrointestinal parasites of cat and faecal consistency.
- ✓ Postmortem examination positivity for adult gastrointestinal parasites of dogs.

List of independent variables for prevalence study of gastrointestinal parasites in dog and cat:

- ✓ Agro-ecology, sex, age, breed, feeding and housing conditions, and origin of sampled animals.

3.9. Ethical considerations

The Addis Ababa University, College of Veterinary Medicine and Agriculture's ethical committee approved and provided information on the animal study's ethical concerns. The ethical approval for animal handling was obtained before the study's start. The Addis Ababa University, College of Veterinary Medicine Research Ethics (AAU-CVMA-REC), and the animal welfare guide for the care and use of animals (Ref. No. VM/ERC/36/02/15/2023) were followed in all animal handling and sample collection procedures (Appendix 4).

4. RESULTS

4.1. Prevalence and associated risk factors of gastrointestinal parasites of dogs

4.1.1. Overall prevalence of gastrointestinal parasites in dogs

A total of 701 dogs from Bishoftu, Dukem, Addis Ababa and Sheno were analyzed using coproscopic methods. In total, 372 dogs (53.1%) were positive for at least one type of gastrointestinal parasite. Of these, cestode segments and adult roundworms were observed grossly in the faecal samples with frequency/proportions of 13 (1.9%) and 11 (1.6%), respectively (Figures 8-15). The prevalence of GI parasites was significantly (P<0.001) lower at Bishoftu compared to the other study sites. Female dogs (P<0.001) and adult dogs (P=0.006) had a considerably greater prevalence of gastrointestinal parasites among the sampled dogs. When compared to dogs with better handling conditions, the prevalence of GI parasites was significantly (P<0.001) greater in dogs that were housed free outdoors. Dogs that were commonly fed uncooked animal products had a higher chance of acquiring parasitic infections than those with cooked food (P<0.001). The odds ratio (OR) of gastrointestinal parasite presence was about 3 times higher for those dogs with uncooked feeding experience. Dogs were with dry faecal consistency (8%), diarrheic faecal consistency (17%), and wet faecal consistency (75%). The prevalence of GI parasites was substantially (P<0.001) greater in dogs from highland regions (Addis Ababa and Sheno) than in dogs from midland regions (Bishoftu and Dukem) (Table 12-14).

The prevalence of gastrointestinal parasites with single parasite infection was significantly (P<0.001) higher than infection with mixed parasite infection (Table 15). Nematodes had significantly (P<0.001) higher prevalence compared to cestodes and protozoans (Table 16).

4.1.2. Prevalence of gastrointestinal parasites by origin of dogs and parasite egg densities

Ancylostoma spp. was the most prevalent gastrointestinal parasite and *Strongyloides stercoralis, Physaloptera* spp. and *Diphyllobothrium* spp. were the least prevalent gastrointestinal parasites in the study areas. A statistically significant (P<0.001) difference in the prevalence of specific gastrointestinal parasites in dogs of the four study sites was observed (Table 17). The density of eggs of parasites as the total mean egg per gram (EPG) of faeces of 1176.8 was recorded (Table 18).

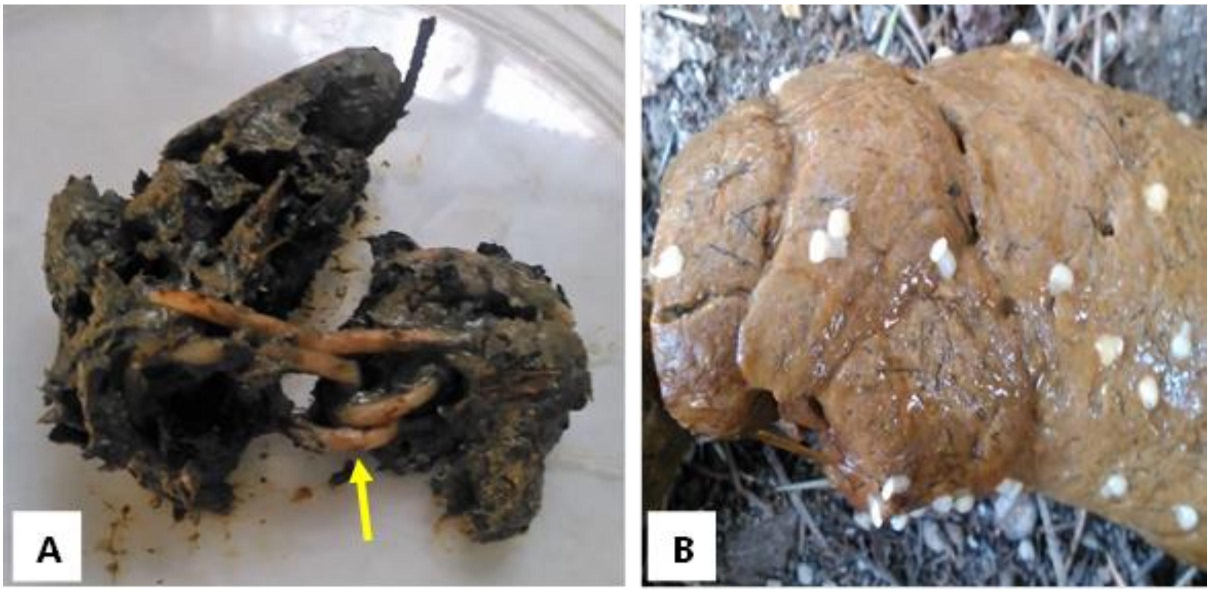

Figure 8. Roundworm (*Toxocara canis*) of 4-month-old male dog (A) and tapeworm segments (*Dipylidium caninum*) from 2-year-old female dog (B) from Bishoftu town. (Source: Author's own work).

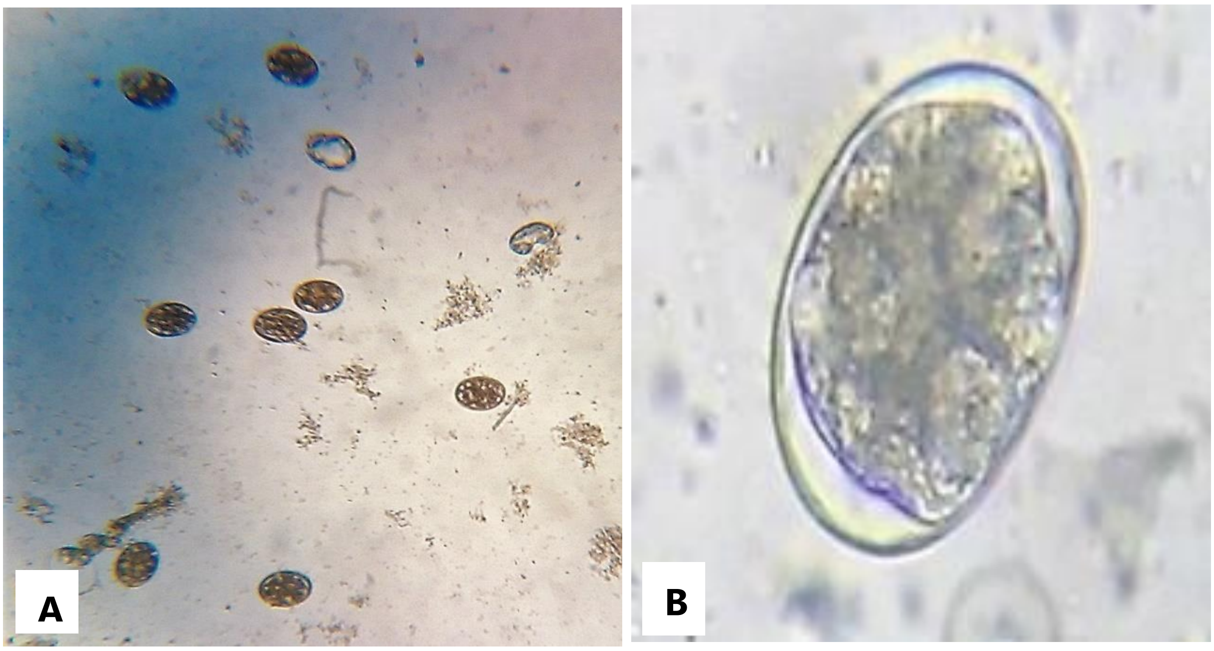

Figure 9. *Ancylostoma* spp. from 2 yrs. female dog x10 (A) and x40 (B) from Bishoftu. (Source: Author's own work).

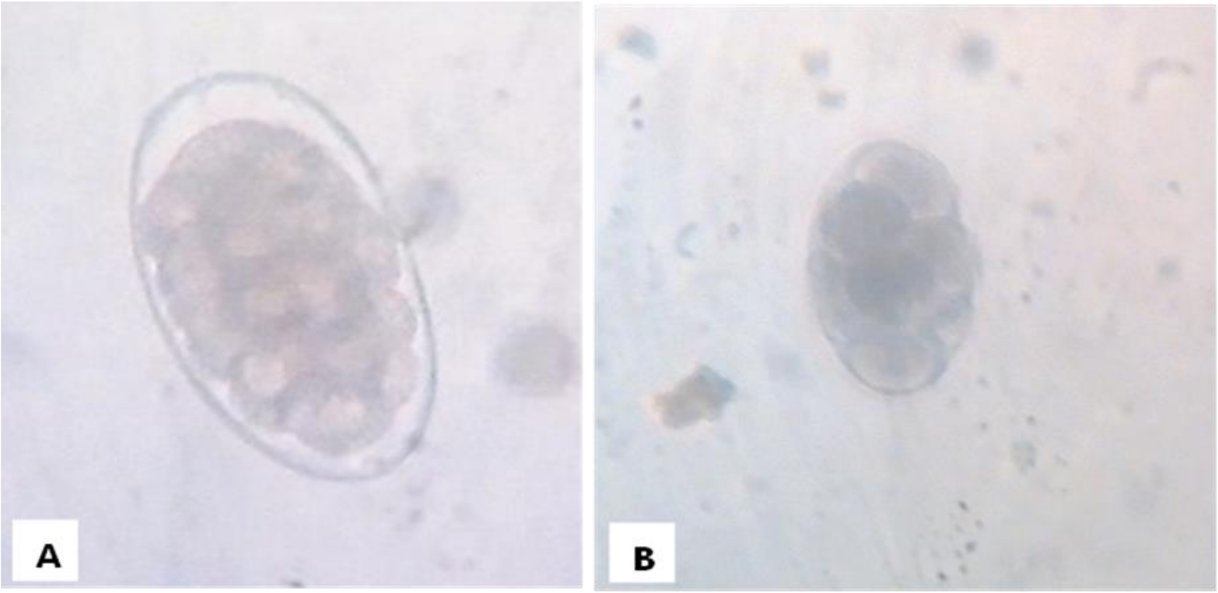

Figure 10. Ancylostoma spp. from 3 yrs. male dog x40 from Dukem town (A). Dipylidium caninum of 4 yrs. old male dog x40 from Addis Ababa (B). (Source: Author's own work).

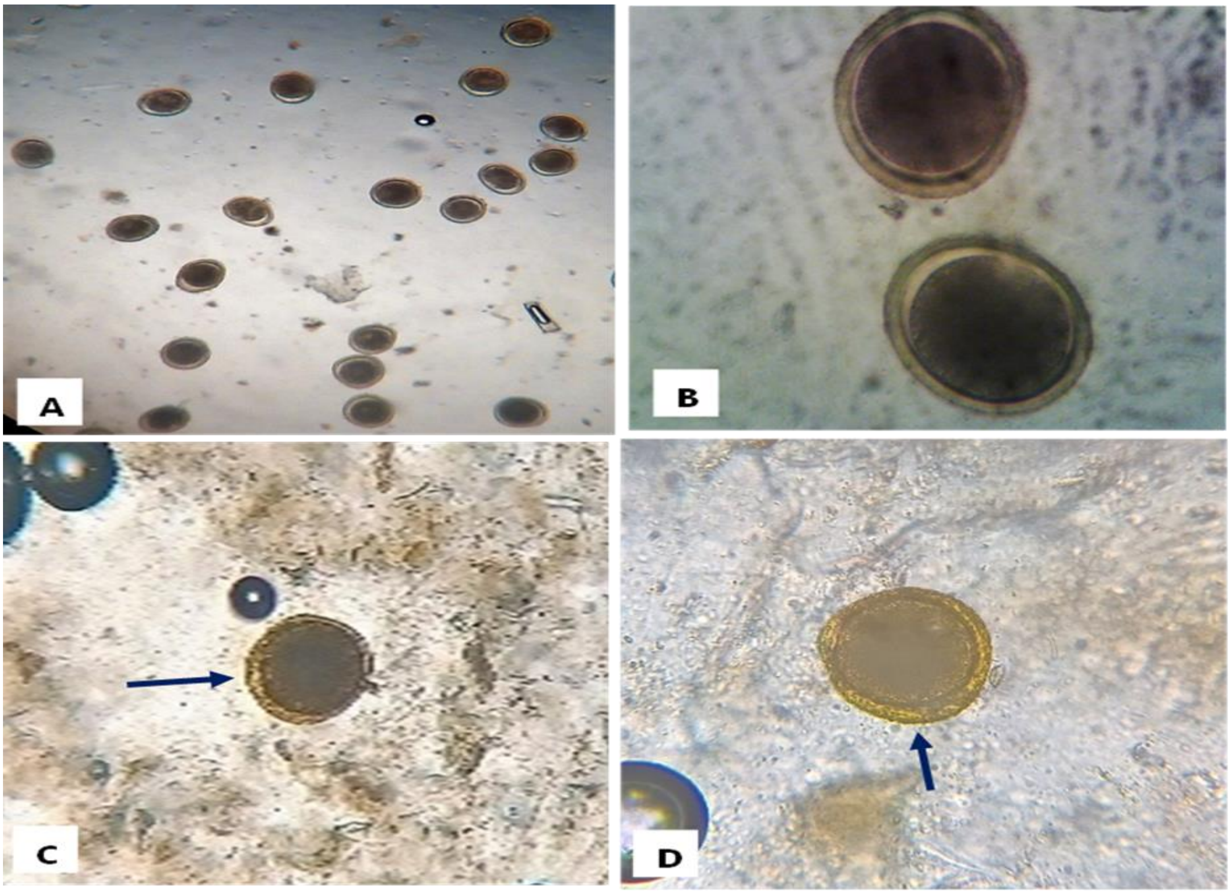

Figure 11. *Toxocara canis* of 1.5 years male dog x10 (A) and x40 (B) from Bishoftu town. *Toxocara canis* of 2 yrs. male dog x10 (C) and x40 (D) from Sheno town. (Source: Author's own work).

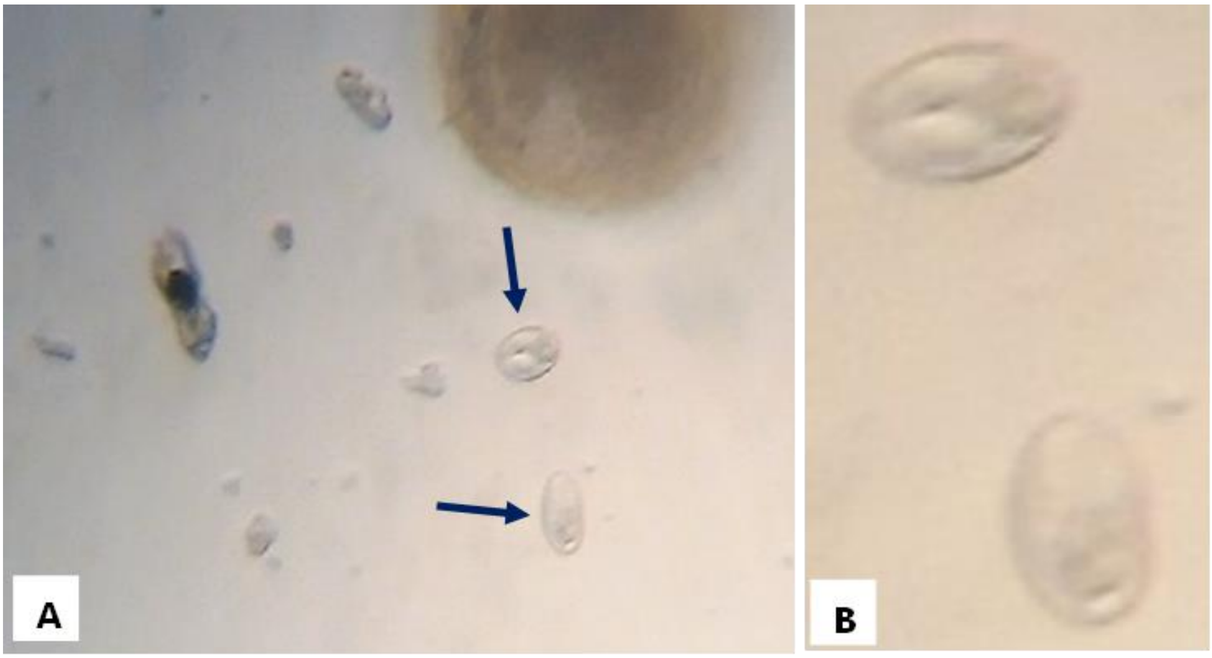

Figure 12. Giardia spp. from a 4-year-old male dog x10 (A) and x40 (B) from Dukem town. (Source: Author's own work).

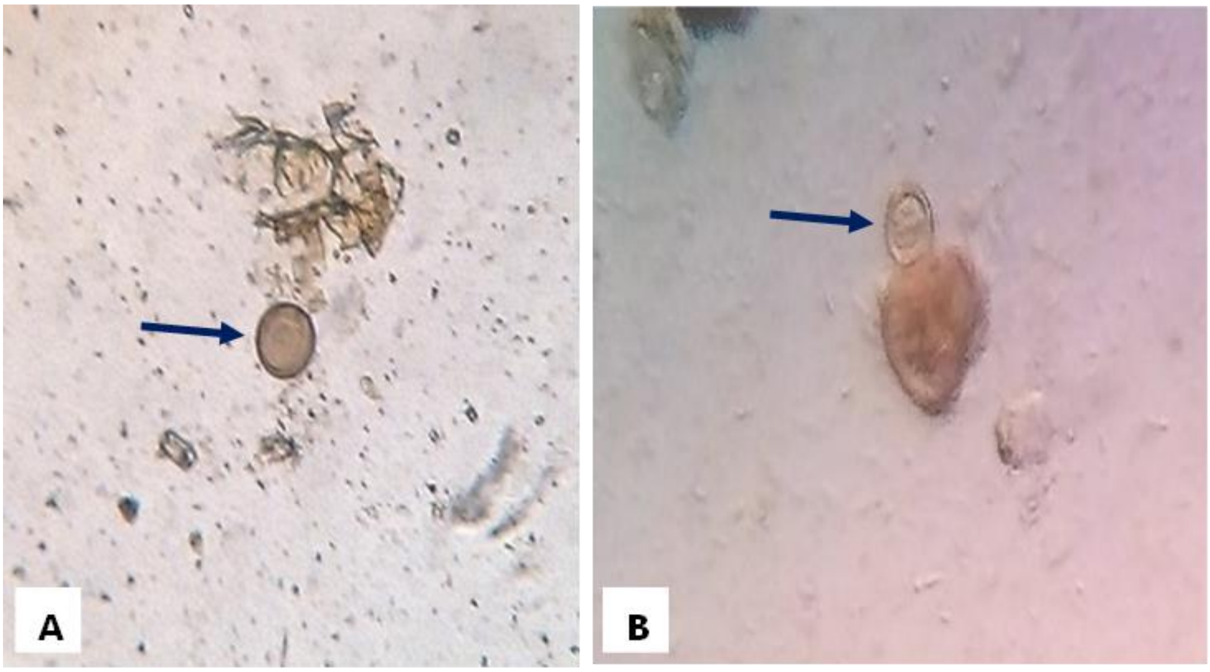

Figure 13. *Taenia/Echinococcus* spp. from 3 yrs. male dog (A) and from 2 yrs. male dog (B) x10 from Sheno town. (Source: Author's own work).

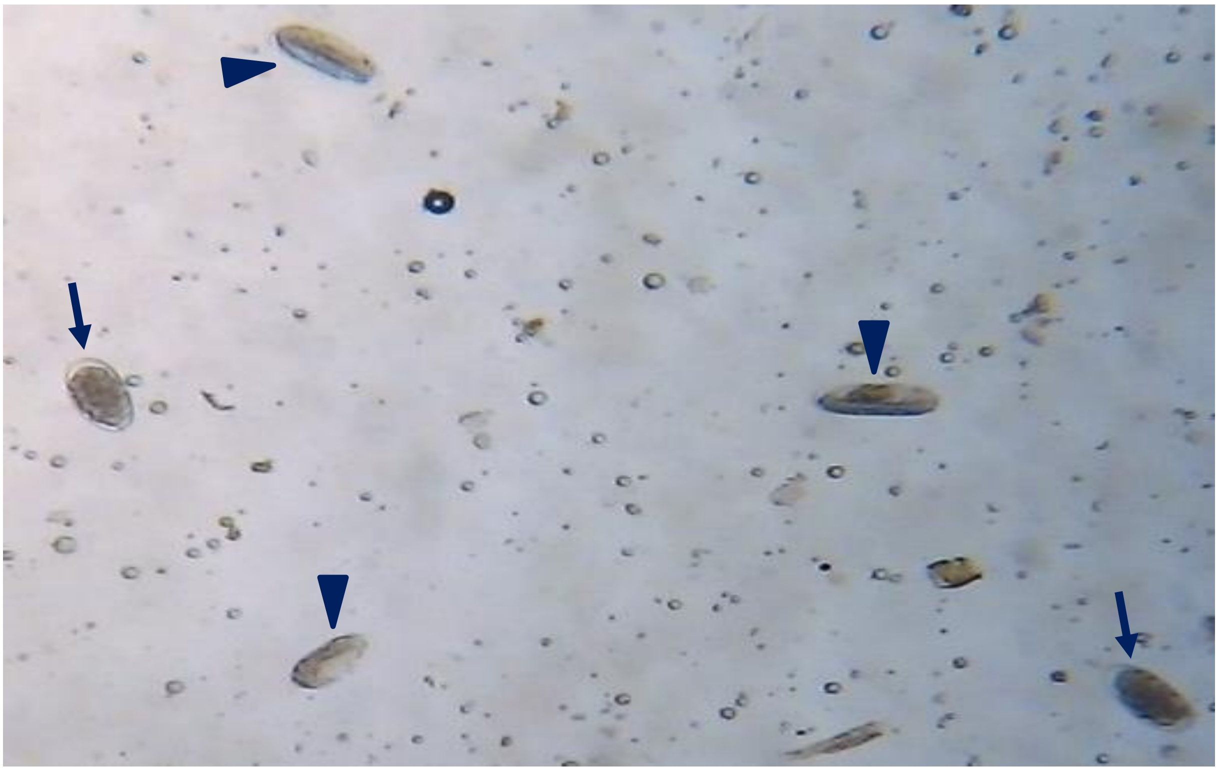

Figure 14. Mixed infection of *Ancylostoma* spp. (arrow) and *Physaloptera* spp. (arrowhead) from 2yrs. female dog x10 from Bishoftu town. (Source: Author's own work).

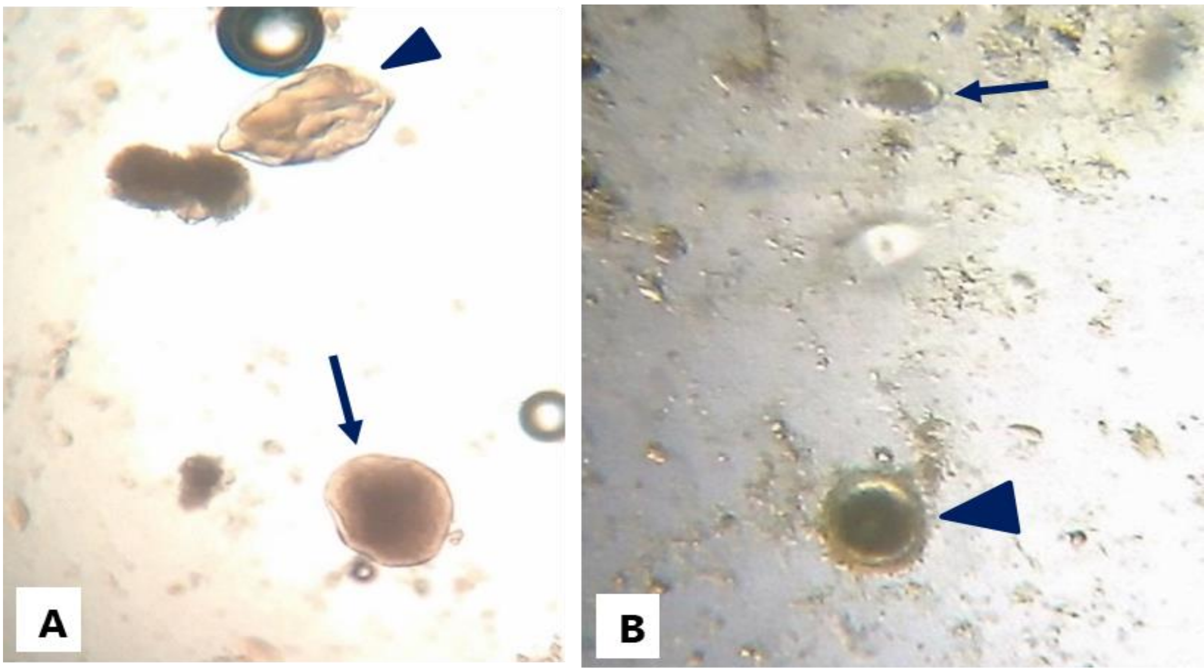

Figure 15. Mixed infection of *Toxocara canis* (arrow) and *Physaloptera* spp. (arrowhead) from3 yrs. male dog x10 from Sheno town (A). *Ancylostoma* spp. (arrow) and *Toxocara canis* (arrowhead) from 4-year-old male dog x10 from Dukem town (B). (Source: Author's own work).

Table 12. Relative prevalence of gastrointestinal parasites in dogs based on animal related risk factors.

Risk factors	Category level	Number of dogs Examined	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		$\chi2$ (P-value)
						Lower	Upper	
Sex	Male	617	310 (50.2)	46-54	Ref	Ref		16.487 (<0.001)
	Female	84	62 (73.8)	64-83	0.358	0.215	0.597	
Age	Puppy	36	14 (38.9)	22-56	Ref			
	Young	48	17 (35.4)	21-49	0.515	0.259	1.025	10.109 (0.006)
	Adult	617	341 (55.3)	51-59	0.444	0.241	0.819	
Breed	Cross	29	13 (44.8)	26-64	Ref	Ref		
	Local	603	314 (52.1)	48-56	0.748	0.354	1.582	5.120 (0.077)
	Exotic	69	45 (65.2)	54-77	1.726	1.025	2.904	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, $\chi2$: chi-square; Ref: reference.

Table 13. Relative prevalence of gastrointestinal parasites in dogs in different study sites.

Risk factors	Category level	Number of Examined dogs	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		χ2 (P-value)
						Lower	Upper	
Origin	Bishoftu	305	123 (41.6)	35-46	Ref	Ref	-	35.384 (<0.001)
	Dukem	135	87 (64.4)	56-73	2.682	1.762	4.082	
	Addis Ababa	134	83 (61.9)	54-70	2.408	1.587	3.654	
	Sheno	127	79 (62.2)	54-71	2.435	1.591	3.727	
Agro-ecology	Midland	440	210 (47.7)	43-52	Ref	Ref	-	13.529 (<0.001)
	Highland	261	162 (62.1)	56-68	1.792	1.312	2.449	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; Ref: reference.

Table 14. Relative prevalence of gastrointestinal parasites in dogs based on animal management.

Risk factors	Category level	Number of dogs Examined	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		χ2 (P-value)
						Lower	Upper	
Feeding condition	Cooked	141	48 (34.0)	26-42	Ref	Ref	-	25.649 (<0.001)
	Uncooked	560	324 (57.9)	54-62	2.660	1.807	3.915	
Housing condition	Free in home/compound	175	68 (38.9)	25-41	Ref	Ref	-	40.999 (<0.001)
	Kennel/leashed	76	30 (39.5)	28-51	0.750	0.420	1.340	
	Free outdoor	450	274 (60.9)	56-65	2.387	1.452	3.925	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; Ref: reference.

Table 15. Gastrointestinal parasite diversity of dogs examined from the four study sites.

Infection with	Origin				Total Frequency (%)	Prevalence (%)	P-value
	Bishoftu (n=305)	Dukem (n=135)	Addis Ababa (n=134)	Sheno (n=127)			
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite	182 (58.4)	48 (35.6)	51 (38.1)	49 (38.6)	328 (46.9)	46.9	
One parasite	99 (32.5)	71 (52.6)	67 (50)	58 (45.7)	296 (42.2)	53.1	<0.001
Two parasites	15 (4.9)	10 (7.4)	11 (8.2)	14 (11)	50 (7.1)		
Three parasites	9 (3)	6 (4.4)	5 (3.7)	6 (4.7)	26 (3.7)		

Table 16. Groups of gastrointestinal parasites detected from the faeces of examined dogs.

Type of parasite	Origin				Prevalence (%)	Total Prevalence (%)	P-value
	Bishoftu (n=305)	Dukem (n=135)	Addis Ababa (n=134)	Sheno (n=127)			
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite	182 (59.7)	48 (35.6)	51(38)	49 (38.6)	46.9	46.9	
Nematode	69 (22.6)	44 (32.6)	45 (33.6)	40 (31.5)	28.2	53.1	
Cestode	20 (6.6)	16 (11.9)	12 (9)	11 (8.7)	8.7		<0.001
Protozoa	11 (3.6)	11 (8.1)	9 (6.7)	8 (6.3)	5.6		
Mixed infection	23 (7.5)	16 (11.9)	18 (13.4)	20 (15.7)	11		

Table 17. Frequencies and percentages of specific gastrointestinal parasites of dog.

Parasite	Origin								Total Frequency (%)	P-value
	Bishoftu (n=305)		Dukem (n=135)		Addis Ababa (n=134)		Sheno (n=127)			
	N (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI		
Single Parasite Infection										
Nematode										
Ancylostoma spp.	39 (12.8)	9-17	26 (19.3)	13-26	23 (17.2)	11-24	24 (18.9)	12-26	112 (16)	<0.001
Toxocara canis	21 (6.9)	4-10	16 (11.9)	6-18	20 (14.9)	9-21	12 (9.5)	4-15	69 (9.8)	<0.001
Strongyloides stercoralis	6 (1.9)	0-4	1 (0.7)	1-2	1 (0.8)	1-2	1 (0.8)	1-2	9 (1.3)	0.003
Physaloptera spp.	4 (1.3)	0-3	2 (1.5)	1-4	1 (0.8)	1-2	2 (1.6)	1-4	9 (1.3)	0.014
Cestode										
Dipylidium caninum	12 (3.9)	2-6	9 (6.7)	2-11	7 (5.2)	1-9	7 (5.5)	1-10	35 (5)	<0.001
Taenia/Echinococcus spp.	7 (2.3)	1-4	5 (3.7)	0-7	5 (3.8)	0-7	5 (3.9)	1-7	17 (2.4)	0.001
Diphyllobothrium spp.	3 (0.9)	0-2	2 (1.5)	1-4	2 (1.5)	1-4	2 (1.6)	1-4	9 (1.3)	0.034
Protozoa										
Giardia spp.	7 (2.3)	1-4	8 (5.9)	1-9	7 (5.2)	1-8	5 (3.9)	1-7	27 (3.9)	0.001
Isospora spp.	4 (1.3)	0-3	3 (2.2)	0-5	2 (1.5)	1-4	3 (2.4)	0-5	12 (1.7)	0.014
Multiple Parasite Infection										
Ancylostoma spp. and *Toxocara canis*	5 (1.6)	0-3	5 (3.8)	0-7	4 (2.9)	0-6	4 (3.2)	0-6	18 (2.6)	0.006
Ancylostoma spp. and *Physaloptera* spp.	3 (0.9)	0-2	1 (0.7)	1-2	1 (0.8)	1-2	1 (0.8)	1-2	6 (0.9)	0.034
Toxocara canis and *Physaloptera* spp.	3 (0.9)	0-2	1 (0.7)	1-2	1 (0.8)	1-2	4 (3.2)	0-6	9 (1.3)	0.034
Ancylostoma spp. and *Taenia/Echinococcus* spp.	3 (0.9)	0-2	2 (1.5)	1-4	3 (2.2)	0-5	3 (2.4)	0-5	11 (1.6)	0.034
Toxocara spp. and Strongyloides spp.	1 (0.3)	0-1	1 (0.7)	1-2	2 (1.5)	1-4	2 (1.6)	1-4	6 (0.9)	0.223
Ancylostoma spp., *Toxocara* spp. and *Physaloptera* spp.	4 (1.3)	0-3	4 (2.9)	0-6	3(2.2)	0-5	3 (2.4)	0-5	14 (2)	0.014
Ancylostoma spp., *Toxocara* spp. and *Taenia/Echinococcus* spp.	2 (0.7)	0-2	1 (0.7)	1-2	2 (1.5)	1-4	1 (0.8)	1-2	6 (0.9)	0.084
Toxocara spp. *Physaloptera* spp. and *Giardia* spp.	3 (0.9)	0-2	1 (0.7)	1-2	-	-	2 (1.6)	1-4	6 (0.9)	0.034
Total	127 (41.6)	35-46	87 (64.4)	56-73	83 (61.9)	54-70	79 (62.2)	54-71	372 (53.1)	0.021

95% CI: 95% confidence interval; *N*: number.

Table 18. Mean egg per gram of faeces (EPG) of specific gastrointestinal parasites of dog.

Parasite	Number (%) of Dogs infected	EPG		
		Mean	SD	P-value
Single Parasite Infection				
Nematode				
Ancylostoma spp.	112 (16)	979**	1205	
Toxocara canis	69 (9.8)	1479.1***	1477	
Strongyloides stercoralis	9 (1.3)	761.1**	918.8	
Physaloptera spp.	9 (1.3)	1444.4***	1863.8	
Total (nematode)	198 (28.2)	1461.1***	1339.7	<0.001
Cestode				
Dipylidium caninum	35 (5)	1265.7***	1367.4	
Taenia/Echinococcus spp.	17 (2.4)	1175***	1246	
Diphyllobothrium spp.	9 (1.3)	966.7**	903.3	
Total (cestode)	59 (8.7)	2100***	2404.1	<0.001
Protozoa				
Giardia spp.	27 (3.9)	964.8**	1175.9	
Isospora spp.	12 (1.7)	1195.8***	1365	
Total (protozoa)	39 (5.6)	4100***	-	<0.001
Multiple Parasite Infection				
Ancylostoma spp. and *Toxocara canis*	18 (2.6)	1233.3***	1369	
Ancylostoma spp. and *Physaloptera* spp.	6 (0.9)	408.3**	156.3	
Toxocara canis and *Physaloptera* spp.	9 (1.3)	1583.3***	1586	
Ancylostoma spp. *and* *Taenia/Echinococcus* spp.	11 (1.6)	654.6**	843.7	
Toxocara spp. and *Strongyloides* spp.	6 (0.9)	941.7**	770	
Ancylostoma spp.*,* *Toxocara* spp. and *Physaloptera* spp.	14 (2)	860.7**	1227	
Ancylostoma spp., *Toxocara* spp. and *Taenia/Echinococcus* spp.	6 (0.9)	1925***	2048	
Toxocara spp. *Physaloptera* spp. and *Giardia* spp.	6 (0.9)	2166.7***	1440	
Total (mixed infection)	77 (11)	1770***	1974.7	<0.001
Total	372 (53.1)	1176.8***	1533	0.008

SD: Standard deviation; **: mild, EPG <1,000; ***: moderate, 1,000 ≤ EPG < 10,000.

4.1.3. Prevalence of gastrointestinal parasites by sex and age of dogs

Ancylostoma spp. and *Toxocara canis* eggs were the most prevalent gastrointestinal parasites in male and female dogs, respectively (Table 19). Similarly, *Ancylostoma* spp. eggs were commonly identified from adult and young dogs, whereas puppies were mainly affected by *Toxocara canis* (Table 19).

Table 19. Prevalence of specific gastrointestinal parasites of dogs relative to their sex and age.

Parasite	Sex		P-value	Age			P-value
	Male (n=617)	Female (n=84)		Puppy (n=36)	Young (n=48)	Adult (n=617)	
	N (%)	*N (%)*		*N (%)*	*N (%)*	*N (%)*	
Nematode							
Ancylostoma spp.	98 (15.9)	14 (16.7)	0.783	0 (0.0)	7 (14.6)	105 (17)	0.024
Toxocara canis	46 (7.5)	23 (27.4)	<0.001	6 (16.7)	4 (8.3)	59 (9.6)	0.356
Strongyloides stercoralis	7 (1.1)	2 (2.4)	0.341	0 (0.0)	0 (0.0)	9 (1.5)	0.538
Physaloptera spp.	9 (1.5)	0 (0.0)	0.265	0 (0.0)	0 (0.0)	9 (1.5)	0.538
Cestode							
Dipylidium caninum	33 (5.3)	2 (2.4)	0.241	2 (5.6)	1 (2.1)	32 (5.2)	0.628
Taenia/Echinococcus spp.	14 (2.2)	8 (9.5)	<0.001	4 (11.1)	0 (0.0)	18 (2.9)	0.010
Diphyllobothrium spp.	5 (0.8)	4 (4.8)	0.003	0 (0.0)	0 (0.0)	9 (1.5)	0.538
Protozoa							
Giardia spp.	24 (3.9)	3 (3.6)	0.887	2 (5.6)	0 (0.0)	25 (4.1)	0.321
Isospora spp.	12 (1.9)	0 (0.0)	0.197	0 (0.0)	0 (0.0)	12 (1.9)	0.436
Total	248 (40.2)	56 (66.7)	<0.001	14 (38.9)	12 (25)	278 (45.1)	0.006

N: number.

4.1.4. Prevalence of groups of gastrointestinal parasites by feeding and housing conditions of dogs

The present study demonstrated the presence of a higher prevalence of protozoan and cestodes in dogs with uncooked food feeding experience and there was a presence of higher prevalence of mixed parasite infection in dogs with cooked food feeding experience in the study areas (Table 20). Based on housing conditions, there was a higher prevalence of nematode, cestode and protozoan parasites in dogs housed free outdoors (Table 21).

Table 20. Prevalence of groups of gastrointestinal parasites of dog relative to their feeding condition.

Feeding condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Cooked (n=141)	91 (64.5)	23 (16.3)	6 (4.3)	3 (2.1)	18 (12.8)	<0.001
Uncooked (n=560)	237 (42.3)	175 (31.3)	53 (9.5)	36 (6.4)	59 (10.5)	

N: number.

Table 21. Prevalence of group of gastrointestinal parasites of dog relative to their housing condition.

Housing condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Kennel/leashed (n=76)	46 (60.5)	18 (23.7)	6 (7.9)	0 (0.0)	6 (7.9)	<0.001
Free in home/compound (n=175)	105 (60)	35 (20)	9 (5.1)	10 (5.7)	16 (9.1)	
Free outdoor (n=450)	177 (39.3)	145 (32.2)	44 (9.8)	29 (6.4)	55 (12.2)	
Total	328 (46.8)	198 (28.2)	59 (8.4)	39 (5.6)	77 (11)	

N: number.

4.1.5. Gastrointestinal helminth parasites of dogs recovered during postmortem examination

From the thirteen dogs of Bishoftu town, which were examined by postmortem technique to detect any adult gastrointestinal helminth parasites, only one four-month-old puppy was found to have an intestine packed with *Toxocara canis* (Figures 16 and 17).

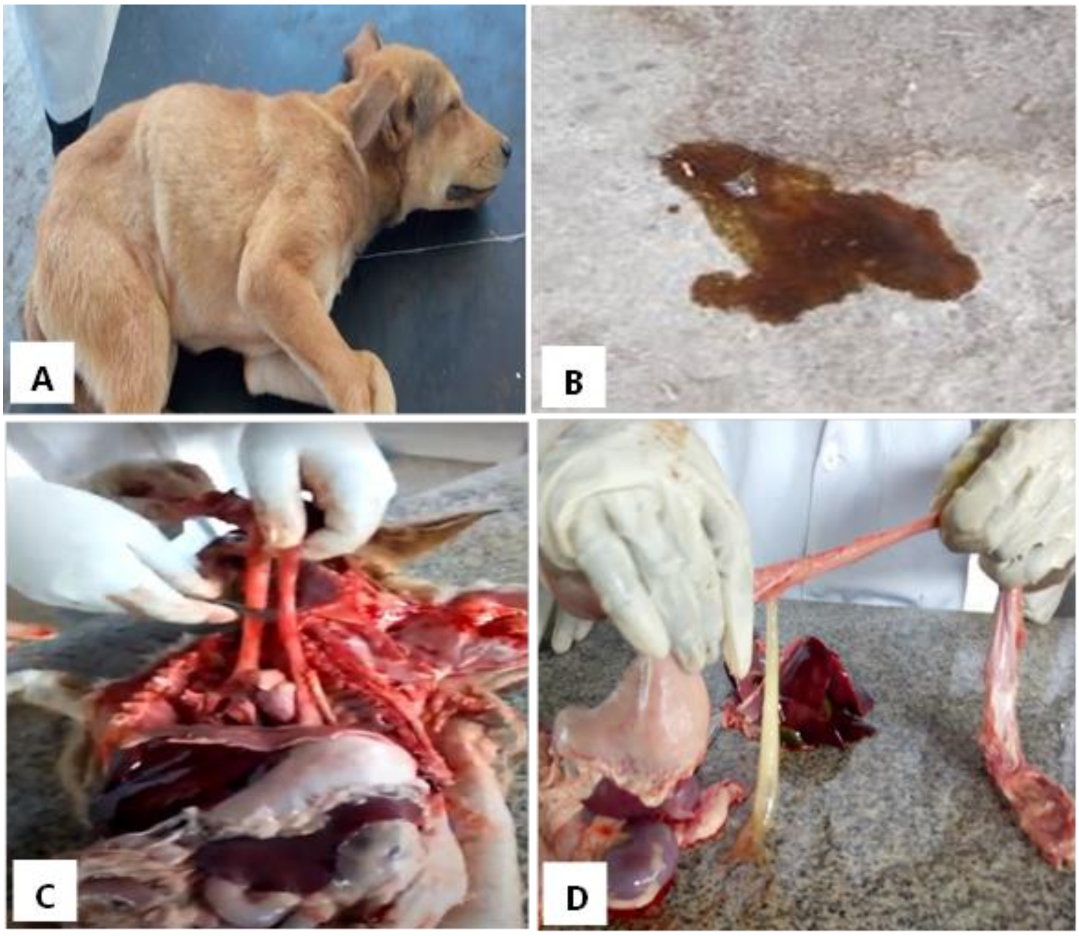

Figure 16. A diarrheic four-month-old puppy (A and B) and its gastrointestinal tracts (C and D). (Source: Author's own work).

Figure 17. Intestine of a four-month-old puppy packed with round worms (*Toxocara canis*). (Source: Author's own work).

4.2. Prevalence and associated risk factors of gastrointestinal parasites of cats

4.2.1. Overall prevalence of gastrointestinal parasites in cats

A total of 213 owned cats from Bishoftu, Dukem and Addis Ababa were analyzed using coproscopic methods. Overall, 74 (34.7%) cats were positive for at least one type of gastrointestinal parasite (Figure 18). The prevalence of GI parasites was lower at Addis Ababa compared to the other study sites. From these sampled cats, the prevalence of gastrointestinal parasites was significantly higher in female (P=0.012) and in young (P=0.016) cats. The odds ratio (OR) of GI parasite presence was about 5 times higher in young cats compared to the adult ones. Cats which were housed free outdoors had a higher prevalence of GI parasites compared to the cats with free in home/compound housing condition. Cats that were commonly fed uncooked animal products had a higher chance of acquiring parasitic infections than those with cooked food (P<0.001). The OR of gastrointestinal parasite presence was about 4 times higher for those cats that had experienced uncooked food feeding experience. Cats were with dry faecal consistency (10%), diarrheic faecal consistency (12%), and wet faecal consistency (78%). Cats from midland areas (Bishoftu and Dukem) had a higher prevalence of GI parasites compared to cats originated from the highland area (Addis Ababa) (Table 22-24).

Table 22. Relative prevalence of gastrointestinal parasites in cats based on animal-related risk factors.

Risk factors	Category Level	Number of cats Examined	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		χ2 (P-value)
						Lower	Upper	
Sex	Male	160	48 (30)	23-37	Ref	Ref	-	6.377 (0.012)
	Female	53	26 (49.1)	35-63	2.247	1.190	4.244	
Age	Young	10	7 (70)	35-100	4.736	1.187	18.898	5.753 (0.016)
	Adult	203	67 (33)	26-40	Ref	Ref	-	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; Ref: reference.

Table 23. Relative prevalence of gastrointestinal parasites in cats in different study sites.

Risk factors	Category Level	Number of cats Examined	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		χ2 (P-value)
						Lower	Upper	
Origin	Addis Ababa	55	17 (30.9)	18-44	Ref	Ref	-	1.053 (0.591)
	Bishoftu	103	35 (33.9)	25-43	1.295	0.659	2.547	
	Dukem	55	22 (40)	27-53	0.869	0.431	1.754	
Agro-ecology	Highland	55	17 (30.9)	18-44	Ref	Ref	-	0.480 (0.488)
	Midland	158	57 (36.1)	29-44	1.262	0.654	2.435	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; Ref: reference.

Table 24. Relative prevalence of gastrointestinal parasites in cats based on animal management.

Risk factors	Category Level	Number of Cats Examined	Number of Positive (%)	95% CI	AOR	95% CI Per AOR		χ2 (P-value)
						Lower	Upper	
Feeding condition	Cooked	50	8 (16)	5-27	Ref	Ref	-	10.123 (0.001)
	Uncooked	163	66 (40.5)	33-48	3.572	1.576	8.096	
Housing condition	Free in home/compound	53	18 (34)	6-40	Ref	Ref	-	6.777 (0.079)
	Free outdoor	160	56 (35)	28-42	0.898	-	-	

95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; Ref: reference.
Note: Cats that were housed in kennel, open air in the compound, and share shelter with family are categorized as cats free in home/compound. Whereas cats that were free roaming in and outside the compound/home are categorized as cats free outdoor.

The prevalence of gastrointestinal parasites with single parasite infection was significantly (P<0.001) higher than infection with mixed parasite infection (Table 25). Overall, nematodes had a higher prevalence compared to cestodes and protozoans (Table 26).

Table 25. Gastrointestinal parasite diversity of cats examined from the three study sites.

Infection with	Origin			Total Percentage	Total Prevalence (%)	P-value
	Bishoftu (n=103)	Dukem (n=55)	Addis Ababa (n=55)			
	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite	68 (66)	33 (60)	38 (69.1)	65.3	65.3	
One parasite	34 (33)	20 (36.4)	16 (29.1)	32.9	34.7	<0.001
Two parasites	1 (0.9)	2 (3.6)	1 (1.8)	1.8		

Table 26. Group of gastrointestinal parasites detected from the faeces of examined cats.

Group of parasites	Origin			Prevalence (%)	P-value
	Bishoftu	Dukem	Addis Ababa		
	Frequency (%)	Frequency (%)	Frequency (%)		
No parasite (n=139)	68 (48.9)	33 (23.7)	38 (27.3)	65.3	0.869
Nematode (n=31)	17 (54.8)	8 (25.8)	6 (19.4)	14.6	
Cestode (n=27)	13 (48.2)	8 (29.6)	6 (22.2)	12.7	
Protozoa (n=12)	4 (33.3)	4 (33.3)	4 (33.3)	5.6	
Mixed infection (n=4)	1 (25)	2 (50)	1 (25)	1.9	

Note: no significant (p=0.869) differences in the prevalence of group of parsites were associated with study sites.

4.2.2. Prevalence of gastrointestinal parasites by origin of cats and parasite egg densities

Toxocara cati was the most prevalent gastrointestinal parasite in the study areas, and *Strongyloides stercoralis* and *Isospora* spp. were the least prevalent gastrointestinal parasites. Statistically significant difference in the prevalence of gastrointestinal parasites in cats of the three study sites wasn’t observed (Table 27). The density of eggs of parasites as the total mean egg per gram (EPG) of faeces of 902.6 was recorded (Table 28).

Table 27. Frequencies and percentages of specific gastrointestinal parasites of cats.

Parasites	Origin						Total Frequency (%)	P-value
	Bishoftu (n=103)		Dukem (n=55)		Addis Ababa (n=55)			
	N (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI		
Single Parasite Infection								
Nematode								
Ancylostoma spp.	2 (1.9)	0-6	1 (1.8)	0-5	1 (1.8)	0-5	4 (1.9)	0.870
Toxocara cati	10 (9.7)	4-16	6 (10.9)	2-19	4 (7.3)	0-14	20 (9.4)	0.798
Strongyloides stercoralis	1 (0.9)	0-3	0 (0.0)	-	0 (0.0)	-	1 (0.5)	0.585
Physaloptera spp.	4 (3.88)	0-8	1 (1.8)	0-5	1 (1.8)	0-5	6 (2.8)	0.661
Cestode								
Dipylidium caninum	10 (3.8)	5-17	5 (9.1)	2-19	4 (7.3)	1-17	19 (8.9)	0.940
Taenia spp.	3 (2.9)	0-6	3 (5.5)	0-14	2 (3.6)	0-12	8 (3.8)	0.445
Protozoa								
Giardia spp.	2 (1.9)	0-10	2 (3.6)	0-12	2 (3.6)	0-12	6 (2.8)	0.993
Giardia trophozoites	1 (0.9)	0-3	2 (3.6)	0-9	2 (3.6)	0-9	5 (2.3)	0.439
Isospora spp.	1 (0.9)	0-3	0 (0.0)	-	0 (0.0)	-	1 (0.5)	0.585
Multiple Parasite Infection								
Ancylostoma spp. and *Taenia* spp.	0 (0.0)	-	1 (1.8)	0-3	0 (0.0)	-	1 (0.5)	0.236
Toxocara spp. and *Strongyloides* spp.	1 (0.9)	0-3	1 (1.8)	0-3	1 (1.8)	0-5	3 (1.4)	0.872
Total	35 (33.9)	25-43	22 (40)	27-53	17 (31)	18-44	74 (34.7)	0.591

95% CI: 95% confidence interval; *N*: number.

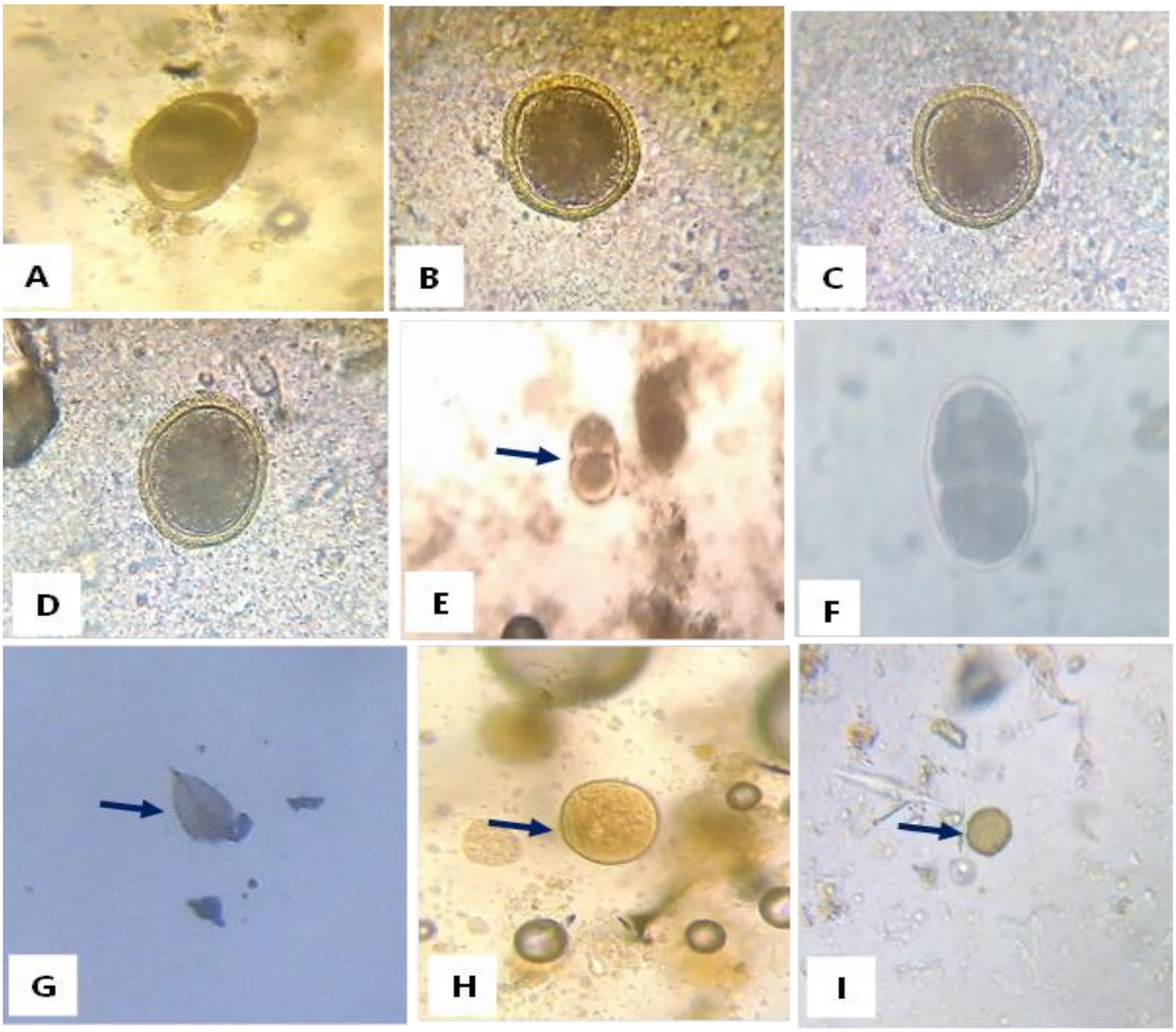

Figure 18. *Toxocara cati* eggs x40 (A-D), Sporulated *Isospora* spp. oocysts x10 (E) and x40 (F) and *Giardia trophozoite* x10 (G) from cats' faecal samples from Bishoftu town, and eggs of *Taenia* spp. x40 (H) and x10 (I) from Addis Ababa. (Source: Author's own work).

Table 28. Mean egg per gram of faeces (EPG) of specific gastrointestinal parasites of cats.

Parasite	Number (%) of Cats infected	EPG		
		Mean	SD	P-value
Single Parasite Infection				
Nematode				
Ancylostoma spp.	4 (1.9)	680**	837.2	
Toxocara cati	20 (9.4)	857.5**	1294	
Strongyloides stercoralis	1 (0.5)	150**	-	
Physaloptera spp.	6 (2.8)	2366.7***	1811.8	
Total (nematode)	31 (14.6)	1116.3***	1442.9	<0.001
Cestode				
Dipylidium caninum	19 (8.9)	1152.3***	1539.7	
Taenia spp.	8 (3.8)	1070***	1445	
Total (cestode)	27 (12.7)	1179.6***	1485.5	<0.001
Protozoa				
Giardia spp.	6 (2.8)	741.7**	1167.4	
Giardia trophozoites	5 (2.3)	2460***	1207.5	
Isospora spp.	1 (0.5)	250**	-	
Total (protozoa)	12 (5.6)	1466.7***	1404	<0.001
Multiple Parasite Infection				
Ancylostoma spp. *and Taenia* spp.	1 (0.5)	100**	-	
Toxocara spp. *and Strongyloides* spp.	3 (1.4)	100**	-	
Total (mixed infection)	4 (1.9)	100**	-	
Total	74 (34.7)	902.6**	1419	<0.001

SD: Standard deviation; **: mild, EPG <1,000; ***: moderate, 1,000 ≤ EPG < 10,000.

4.2.3. Prevalence of specific gastrointestinal parasites by sex and age of cats

Toxocara cati was the most prevalent gastrointestinal parasite in male cats, whereas *Taenia* spp. were the most prevalent gastrointestinal parasites in female cats (Table 29). Similarly, *Ancylostoma* spp., *Taenia* spp. and *Toxocara cati* were commonly identified in young cats, whereas *Toxocara cati* and *Dipylidium caninum* were the most prevalent gastrointestinal parasites in adult cats (Table 29).

Table 29. Prevalence of specific gastrointestinal parasites of cat relative to their sex and age.

Parasite	Sex		P-value	Age		P-value
	Male (n=160)	Female (n=53)		Young (n=10)	Adult (n=203)	
	N (%)	*N (%)*		*N (%)*	*N (%)*	
Nematode						
Ancylostoma spp.	4 (2.5)	0 (0.0)	0.245	1 (10)	3 (1.5)	0.053
Toxocara cati	16 (10)	4 (7.5)	0.596	1 (10)	19 (9.4)	0.946
Strongyloides stercoralis	1 (0.6)	0 (0.0)	0.564	0 (0.0)	1 (0.5)	0.824
Physaloptera spp.	6 (3.8)	0 (0.0)	0.153	0 (0.0)	6 (3)	0.581
Cestode						
Dipylidium caninum	14 (8.8)	5 (9.4)	0.880	0 (0.0)	19 (9.4)	0.311
Taenia spp.	0 (0.0)	8 (15.1)	<0.001	1 (10)	7 (3.4)	0.287
Protozoa						
Giardia spp.	2 (1.2)	4 (7.5)	0.016	0 (0.0)	6 (3)	0.581
Giardia trophozoites	0 (0.0)	5 (9.4)	<0.001	0 (0.0)	5 (2.5)	0.616
Isospora spp.	1 (0.6)	0 (0.0)	0.564	0 (0.0)	1 (0.5)	0.824
Total	44 (27.5)	26 (49.1)	0.012	3 (30)	67 (33)	0.016

N: number.

4.2.4. Prevalence of groups of gastrointestinal parasites by feeding and housing conditions of cats

The present study demonstrated the presence of a higher prevalence of nematodes in cats with uncooked feeding experience and there was a presence of higher prevalence of mixed parasite infection in cats with cooked food feeding experience in the study areas (Table 30). Based on housing conditions, there was a higher prevalence of nematode, protozoan, and mixed parasites in cats housed free outdoors (Table 31).

Table 30. Prevalence of groups of gastrointestinal parasites of cats relative to their feeding condition.

Feeding condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Cooked (n=50)	42 (84)	2 (4)	1 (2)	1 (2)	4 (8)	<0.001
Uncooked (n=163)	97 (59.5)	29 (17.8)	26 (16)	11 (6.7)	0 (0.0)	

N: number.

Table 31. Prevalence of groups of gastrointestinal parasites of cats relative to their housing condition.

Housing condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Free in home/compound (n=53)	35 (66)	6 (11.3)	10 (18.9)	2 (3.8)	0 (0.0)	0.079
Free outdoor (n=160)	104 (65)	25 (15.6)	17 (10.6)	10 (6.3)	4 (2.5)	

N: number.

4.3. Knowledge, attitude and practices of dog and cat owners toward gastrointestinal parasites of dogs and cats

4.3.1. Socio-demographic characteristics of dog and cat owners

Of the total of 272 respondents, 172 (63.2%) and 100 (36.8%) of them were dog owners and cat owners, respectively, from Bishoftu, Dukem and Addis Ababa. In this survey, the majority of the respondents were males with the age range of 31-50 years. Based on education level, 36.8% of the respondents had non-formal education/Illiterate, followed by secondary school graduates and college/university level with proportions of 25.4% and 22.8%, respectively. The majority of the respondents were livestock/poultry keepers and followed by civil servants and merchants (Table 32).

Table 32. Summary of socio-demographic characteristics of dog and cat owners.

Variable	Category	Total Frequency (%)	Dog Owners (n=172)	Cat Owners (n=100)
			N (%)	*N* (%)
Districts	Bishoftu	136 (50)	86 (50)	50 (50)
	Dukem	50 (18)	0 (0.0)	50 (50)
	Addis Ababa	86 (31.6)	86 (50)	0 (0.0)
Sex	Male	191 (70.2)	120 (70)	71 (71)
	Female	81 (29.8)	52 (30.2)	29 (29)
Age	18-30 yrs.	47 (17.3)	30 (17.4)	17 (17)
	31-50 yrs.	141 (51.8)	88 (51.2)	53 (53)
	> 50 yrs.	84 (30.9)	54 (31.4)	30 (30)
Education level	Non-formal education/ Illiterate	100 (36.8)	66 (38.4)	34 (34)
	Primary school	41 (15.1)	26 (15.1)	15 (15)
	Secondary education	69 (25.4)	42 (24.4)	27 (27)
	College/University	62 (22.8)	38 (22.1)	24 (24)
Occupation	Crop farming	20 (7.4)	14 (8.1)	6 (6)
	Livestock/poultry keeping	104 (38.2)	66 (38.4)	38 (38)
	Civil servant/ Professional	88 (32.4)	52 (30.2)	36 (36)
	Merchant	60 (22.1)	40 (23.3)	20 (20)

N: number

4.3.2. Pet ownership and purpose for keeping dogs and cats

From the total respondents, the majority (69.9%) of the respondents kept their dog or cat for more than three years, and of the respondents, 48.2% kept their pet as a companion animal, while 29.4% did so for guarding purposes (Table 33).

Table 33. Pet ownership and purpose for keeping their pet.

Variable	Category	Total Frequency (%)	Dog Owners (n=172)	Cat Owners (n=100)	P-value
			N (%)	*N* (%)	
Experience of keeping pets (Years)	< 1	48 (17.6)	30 (17.4)	18 (18)	0.830
	1-3	34 (12.5)	20 (11.6)	14 (14)	
	> 3	190 (69.9)	122 (70.9)	68 (68)	
Purpose of keeping the pets	Guarding	131 (48.2)	131 (76.1)	0 (0.0)	<0.001
	Chase rodents	53 (19.5)	0 (0)	53 (53)	
	Companion	80 (29.4)	33 (19.2)	47 (47)	
	Look after livestock	8 (2.9)	8 (4.6)	0 (0.0)	

N: number

4.3.3. Knowledge of dog and cat owners toward dog and cat gastrointestinal parasites and their associated zoonosis

From the total participants, the majority of them were found to have an awareness of what gastrointestinal parasites are and they knew that dogs and cats can have gastrointestinal parasites. *Ascarids* and *cestodes* were the main parasites mentioned by dog and cat owners. Diarrhea, vomiting, weight loss and inappetence were mentioned by the participants as the main clinical signs of gastrointestinal parasite infection in dogs and cats. Regarding modes of transmission, the majority of the participants knew the main mechanisms of transmission, and faecal contamination and contact with infected ones were mentioned as main mechanisms of transmission. Cleaning the environment, cleaning and disinfecting, feeding cooked offal/meat, and deworming pets regularly were mentioned by pet owners as the main mechanisms to control/prevent the parasites.

Of the participants, the majority were aware of dog and cat gastrointestinal parasitic zoonosis and *ascarids* (locally named as “Wosefat”) and *cestodes* (locally called “Kosso”) were mentioned as main zoonotic gastrointestinal parasites. Eating raw meat/vegetables, faecal contamination and contact with infected pets were mentioned by animal owners as the main modes of transmission of the parasites to humans. It was found that the average KAP score of dog and cat owners' awareness of gastrointestinal parasites in their pets was 54.6% and 63.9% for dog and cat owners, respectively, which indicated that the dog and cat owners had good knowledge of gastrointestinal parasites of dogs/cats (Table 34).

Table 34. Knowledge of dog and cat owners toward gastrointestinal parasites of dog and cat and their associated zoonosis.

Variable	Category	Total Frequency (%)	Dog Owners (n=172) *N* (%)	KAP Score (%) of Dog Owners	Cat Owners (n=100) *N* (%)	KAP Score (%) of Cat Owners	P-value
Know what gastrointestinal parasites are	Yes	144 (52.9)	90 (52.3**)	52.3	54 (54**)	54	0.790
	No	128 (47.1)	82 (47.7)		46 (46)		
Know that dogs/cats can have gastrointestinal parasites	Yes	168 (61.8)	108 (62.8**)	62.8	60 (60**)	60	0.648
	No	104 (38.2)	64 (37.2)		40 (40)		
Mention some gastrointestinal parasites of dogs/cats	*Ascarids*	64 (23.5)	50 (29.1)		14 (14)		0.011
	Cestodes	33 (12.1)	22 (12.8)		11 (11)		
	No parasites	175 (64.3)	100 (58.1)		75 (75)		
Know any clinical sign of gastrointestinal parasite infection in dogs/cats	Yes	157 (57.7)	100 (58.1**)	58.1	57 (57**)	57	0.854
	No	115 (42.3)	72 (41.9)		43 (43)		
Mention some main clinical signs	Diarrhoea	49 (18)	28 (16.3)		21 (21)		0.770
	Vomiting	29 (10.7)	18 (10.5)		11 (11)		
	Weight loss	47 (17.3)	28 (16.3)		19 (19)		
	Inappetence	18 (6.6)	12 (6.9)		6 (6)		
	Do not know	129 (47.4)	86 (50)		43 (43)		
Know the mode of transmission of gastrointestinal parasites from animal to animal	Yes	165 (60.7)	106 (61.7**)	61.7	59 (59**)	59	0.669
	No	107 (39.3)	66 (38.4)		41 (41)		
Mention the main modes of transmission	Faecal contamination	63 (23.2)	40 (23.3)		23 (23)		0.589
	Contact with infected ones	102 (37.5)	68 (39.5)		34 (34)		
	Do not know	107 (39.3)	64 (37.2)		43 (43)		
Know how to control/prevent gastrointestinal parasites in dogs/cats	Yes	170 (62.5)	104 (60.5**)	60.5	66 (66**)	66	0.363
	No	102 (37.5)	68 (39.5)		34 (34)		

Table 34 (Continued)

Variable	Category	Total Frequency (%)	Dog Owners (n=172) N (%)	KAP Score (%) of Dog Owners	Cat Owners (n=100) N (%)	KAP Score (%) of Cat Owners	P-value
Mention main mechanisms to control/prevent the parasites	Cleaning the environment	78 (28.7)	52 (30.2)		26 (26)		<0.001
	Cleaning and disinfection	42 (15.4)	28 (16.3)		14 (14)		
	Feeding cooked offal/meat/milk	33 (12.1)	22 (12.8)		11 (11)		
	Deworming regularly	17 (6.3)	15 (8.7)		2 (2)		
	Do not know	102 (37.5)	68 (39.5)		34 (34)		
Observe a parasite or segment of parasite in dog/cat excrement	Yes	76 (27.9)	76 (44.2)		0 (0.0)		<0.001
	No	196 (72.1)	96 (55.8)		100 (100)		
Know any gastrointestinal parasites of dogs/cats that can be transmitted to humans	Yes	217 (79.8)	136 (79.1**)	79.1	81 (81**)	81	0.702
	No	55 (20.2)	36 (20.9)		19 (19)		
If yes for the above question, mention some parasites	*Ascarids*	23 (8.5)	14 (8.1)		9 (9)		0.907
	Cestodes	27 (9.9)	18 (10.5)		9 (9)		
	No parasite	222 (81.6)	140 (81.4)		82 (82)		
Know the mode of transmission of gastrointestinal parasites from pet to man	Yes	190 (69.9)	120 (69.8**)	69.8	70 (70**)	70	0.968
	No	82 (30.1)	52 (30.2)		30 (30)		
If yes for the above question, mention the main modes of transmission	Contact with infected pet	124 (45.6)	76 (44.2)		48 (40)		0.875
	Faecal contamination	29 (10.7)	18 (10.5)		11 (11)		
	Eating raw meat/vegetables	29 (10.7)	18 (10.5)		11 (11)		
	Do not know	90 (33.1)	60 (34.9)		30 (30)		
Average KAP score of dog and cat owners' Knowledge toward gastrointestinal parasites of their dog/cat				54.6		63.9	

N: number; **: Proportion considered as KAP score.

4.3.4. Attitude of dog and cat owners toward dog and cat gastrointestinal parasites and their associated zoonosis

Of the participants, the majority were found to think that gastrointestinal parasitosis is a serious disease and they had the awareness that pet ownership can have health risks. According to the responses of pet owners, playing with dogs and cats and feeding raw food to dogs and cats could expose these animals and man to gastrointestinal parasitosis. The majority of the owners indicated that washing hands with water and soap hinders the transmission of gastrointestinal parasites to humans, and they replied that medication/treatment is necessary when dogs and cats experience gastrointestinal parasitosis. The Average KAP score of dog and cat owners' attitude towards gastrointestinal parasites of their dog/cat was found to be 82.1% and 84.1% for dog and cat owners, respectively, which indicated that the dog and cat owners had positive attitude towards gastrointestinal parasites of dog/cat (Table 35).

Table 35. Attitude of dog and cat owners toward dog and cat gastrointestinal parasites and their associated zoonosis.

Variable	Category	Total Frequency (%)	Dog Owners (n=172) *N* (%)	KAP Score (%) of Dog Owners	Cat Owners (n=100) *N* (%)	KAP Score (%) of Cat Owners	P-value
Think gastrointestinal parasitosis is a serious disease	Yes	185 (68)	114 (66.3*)	66.3	71 (71*)	71	0.421
	No	87 (32)	57 (33.1)		30 (30)		
Think pet ownership can have health risks	Yes	185 (68)	116 (67.4*)	67.4	69 (69*)	69	0.422
	No	87 (32)	60 (34.9)		27 (27)		
Think playing with dog/cat may expose human to gastrointestinal parasitosis	Yes	185 (68)	114 (66.3*)	66.3	71 (71*)	71	0.421
	No	87 (32)	58 (33.7)		29 (29)		
Think feeding raw food to dog/cat can cause gastrointestinal parasitosis	Yes	236 (86.8)	148 (86*)	86	88 (88*)	88	0.647
	No	36 (13.2)	24 (14)		12 (12)		
Think washing hands with water and soap reduces the transmission of gastrointestinal parasites to humans	Yes	257 (94.5)	162 (94.2*)	94.2	95 (95*)	95	0.777
	No	15 (5.5)	10 (5.8)		5 (5)		
Think medication/treatment is necessary when your dog/cat experiences gastrointestinal parasitosis	Yes	263 (96.7)	166 (96.5*)	96.5	97 (97*)	97	0.828
	No	9 (3.3)	6 (3.5)		3 (3)		
Think health education can reduce gastrointestinal parasite prevalence	Yes	266 (97.8)	168 (97.7*)	97.7	98 (98*)	98	0.860
	No	6 (2.2)	4 (2.3)		2 (2)		
Average KAP score of dog and cat owners' attitude toward gastrointestinal parasites of their dog/cat				82.1		84.1	

N: number; *: Proportion considered as KAP score.

4.3.5. Management and practices of dog and cat owners toward gastrointestinal parasites

From the total respondents, the majority of them kept their pets free outdoor and fed their pets raw offal/meat/milk followed by scavenging, condemned offal and human food and cooked offal/meat/milk. Among the respondents, the majority of the cats' and dogs' owners were found to clean pets' excrement and dispose it into the toilet by taking the necessary precautions while cleaning the dog and cat houses/environment. From the total respondents, to deworm their pets, 30.2% of the dog owners and 8% of the cat owners took their animals to a veterinary clinic. The majority of the respondents had no usual contact with their dog/cat and had experience of consuming cooked meat/vegetables, and all of them had experience of washing hands before a meal. The Average KAP score of dog and cat owners' practices towards gastrointestinal parasites of their dog/cat was found to be 46% and 37.6% for dog and cat owners, respectively, which indicated that the dog and cat owners had bad/poor practice towards gastrointestinal parasites of dog/cat (Table 36).

Table 36. Management and practices of dog and cat owners towards gastrointestinal parasites.

Variable	Category	Total Frequency (%)	Dog Owners (n=172) *N* (%)	KAP Score (%) of Dog Owners	Cat Owners (n=100) *N* (%)	KAP Score (%) of Cat Owners	P-value
Housing condition of your dog/cat	Kennel/leashed	25 (9.2)	24 (14**)	14	1 (1**)	1	<0.002
	Free outdoor	159 (58.5)	90 (52.3)		69 (69)		
	Free in home/compound	88 (32.4)	58 (33.7)		30 (30)		
Feeding condition of your dog/cat	Cooked offal/meat/milk	34 (12.5)	22 (12.8**)	12.8	12 (12**)	12	0.597
	Raw offal/meat/milk	133 (48.9)	80 (46.5)		53 (53)		
	Scavenging anywhere	57 (21)	38 (22.1)		19 (19)		
	Condemned offal and human food	48 (17.6)	32 (18.6)		16 (16)		
Usual place of defecation of your dog/cat	In public field	107 (39.3)	64 (37.2)		43 (43)		<0.002
	In their cage only	25 (9.2)	24 (14**)	14	1 (1**)	1	
	In the compound/ground/	140 (51.5)	84 (48.8)		56 (56)		
Cleaning and disposing of your dog's/cat's excrement	Clean and bury in the ground	33 (12.1)	22 (12.8)		11 (11)		0.297
	Clean and add to the toilet	126 (46.3)	84 (48.8**)	48.8	42 (42**)	42	
	Clean and dispose with garbage	74 (27.2)	40 (23.3)		34 (34)		
	Do not clean	39 (14.3)	26 (15.1)		13 (13)		
Access to any veterinary service for your dog/cat	Yes	134 (49.3)	96 (55.8**)	55.8	38 (38**)	38	<0.005
	No	138 (50.7)	76 (44.2)		62 (62)		
Veterinary service you have/had for your dog/cat	Vaccination	17 (6.3)	12 (6.9)		5 (5)		<0.001
	Deworming	60 (22.1)	52 (30.2**)	30.2	8 (8**)	8	
	Spaying/neutering	21 (7.7)	16 (9.3)		5 (5)		
	Other services	20 (7.4)	16 (9.3)		4 (4)		
	No service	154 (56.6)	76 (44.2)		78 (78)		

Table 36 (Continued)

Variable	Category	Total Frequency (%)	Dog Owners (n=172) N (%)	KAP Score (%) of Dog Owners	Cat Owners (n=100) N (%)	KAP Score (%) of Cat Owners	P-value
Use protective equipment (like glove, facemasks, boots, gown) during cleaning	Yes	143 (52.6)	96 (55.8**)	55.8	47 (47**)	47	0.160
	No	129 (47.4)	76 (44.2)		53 (53)		
Have usual contact with your dog/cat	Yes	103 (37.9)	62 (36)		41 (41)		0.417
	No	169 (62.1)	110 (64**)	64	59 (59**)	59	
Eat raw meat/vegetable	Yes	92 (33.8)	60 (34.9)		32 (32)		0.628
	No	180 (66.2)	112 (65.1**)	65.1	68 (68**)	68	
Wash your hand before meal	Yes	272 (100)	172 (100**)	100	100 (100**)	100	
	No	0 (0.0)					
Average KAP score of dog and cat owners' practices toward gastrointestinal parasites of their dog/cat				46		37.6	

N: number; **: Proportion considered as KAP score.

4.3.6. Mean knowledge, attitude and practices across the socio-demographic characteristics

The mean knowledge score was higher (1.65±0.39) for Bishoftu than for other districts. The mean attitude score was similar for Bishoftu and Addis Ababa (1.19±0.24), which is higher than the score recorded for Dukem (1.11±0.17). However, the mean practice score was higher (2.31 ± 0.17) for Dukem than for other districts. According to this study, female participants had greater average scores of 1.74± 0.34 and 1.21 ± 0.24 than males for knowledge and attitudes, at $p < 0.001$ and $p = 0.066$, respectively, whereas males had higher mean scores of 2.19±0.26 than females for practices at $p = 0.148$. The mean score for the age group over 50 was higher for knowledge, attitude and practice (1.87±0.29, 1.23±0.27, 2.23±0.28, respectively, at $p<0.001$). Furthermore, there were statistical differences in mean scores between groups based on occupation and educational level (Table 37).

Table 37. Mean knowledge, attitude and practices scores across socio-demographic characteristics.

Variable	Category	Total Frequency	Mean Knowledge Score		Mean Attitude Score		Mean Practice Score	
			Mean	SD	Mean	SD	Mean	SD
Districts	Bishoftu	136	1.65	0.39	1.19	0.24	2.17	0.26
	Dukem	50	1.4	0.32	1.11	0.17	2.31	0.17
	Addis Ababa	86	1.58	0.38	1.19	0.24	2.12	0.24
p-value			<0.001		0.125		<0.001	
Sex	Male	191	1.51	0.39	1.15	0.23	2.19	0.26
	Female	81	1.74	0.34	1.21	0.24	2.15	0.21
p-value			<0.001		0.066		0.148	
Age	18-30 yrs.	47	1.35	0.36	1.07	0.15	2.22	0.22
	31-50 yrs.	141	1.49	0.35	1.17	0.22	2.11	0.21
	> 50 yrs.	84	1.87	0.29	1.23	0.27	2.23	0.28
p-value			<0.001		<0.001		<0.001	
Education level	Non-formal education/ Illiterate	100	1.82	0.24	1.19	0.25	2.19	0.24
	Primary school	41	1.80	0.34	1.26	0.26	2.22	0.27
	Secondary school	69	1.43	0.33	1.21	0.20	2.08	0.22
	College/University	62	1.26	0.15	1.01	0.03	2.19	0.24
p-value			<0.001		<0.001		0.004	
Occupation	Crop farming	20	1.84	0.29	1.41	0.34	2.38	0.21
	Livestock/poultry keeping	104	1.87	0.27	1.24	0.22	2.21	0.24
	Civil servant/ Professional	88	1.27	0.28	1.05	0.15	2.13	0.25
	Merchant	60	1.44	0.29	1.15	0.19	2.13	0.21
p-value			<0.001		<0.001		<0.001	

SD: Standard deviation.

4.3.7. Predictors of the participants' knowledge about gastrointestinal parasites

At a cutoff point of 50% and higher, the survey discovered that 52.9% (144/272) of participants knew about gastrointestinal parasites of dogs and cats. To evaluate the relationship between the knowledge and the possible predictors, Pearson's chi-square was used. There was an association between knowledge and the observed level of owners knowledge on whether they know what gastrointestinal parasites are ($\chi2=189.251$, $p<0.001$), know dogs/cats can have gastrointestinal parasites or not ($\chi2=201.839$, $p<0.001$), on clinical signs ($\chi2=228.099$, $p<0.001$), mode of transmission ($\chi2=208.075$, $p<0.001$), know how to control/prevent gastrointestinal parasites ($\chi2=250.066$, $p<0.001$), know any gastrointestinal parasites of dogs/cats that can be transmitted to humans ($\chi2=67.299$, $p<0.001$) and whether they know the mode of transmission of gastrointestinal parasites from pet to man ($\chi2=198.059$, $p<0.001$). After stepwise binary logistic regression analysis, all mentioned variables were found to be significant predictors of participants' knowledge about gastrointestinal parasites of dogs and cats, and table 38 displays the corresponding adjusted odds ratios (AORs).

Table 38. Summary of likelihood estimates for the predictors associated with the knowledge of the participants about gastrointestinal parasites of dog and cat.

Variable	Category	Number of Participants (n=272)	Knowledgeable (n=144)	Proportion (%)	AOR	95% CI	P-value
Know what GI parasites are	Yes	144	126	87.5	Ref		<0.001
	No	128	18	14.1	2.132	1.150-2.158	
Know dogs/cats can have GI parasites	Yes	168	124	73.8	Ref		<0.001
	No	104	20	19.2	2.818	1.057-4.153	
Know any clinical sign of GI parasites infection in dogs/cats	Yes	157	119	75.8	Ref		<0.001
	No	115	25	21.7	3.132	0.150-2.158	
Know the mode of transmission of GI parasites from animal to animal	Yes	165	117	70.9	Ref		<0.001
	No	107	27	25.2	2.437	0.080-1.240	
Know how to control/prevent GI parasites in dogs/cats	Yes	170	126	74.1	Ref		<0.001
	No	102	18	17.6	13.364	7.232-24.692	
Know any GI parasites of dogs/cats that can be transmitted to humans	Yes	217	135	62.2	Ref		<0.001
	No	55	9	16.4	8.415	3.915-18.088	
Know the mode of transmission of GI parasites from pet to man	Yes	190	129	67.9	Ref		<0.001
	No	82	15	18.3	9.446	4.994-17.866	

95% CI: 95% Confidence interval; GI: Gastrointestinal; AOR: adjusted Odds ratio; Ref: reference category.

5. DISCUSSION

5.1. Gastrointestinal parasitism is a major health problem in dogs and cats

The study's findings showed that gastrointestinal parasites are common in dogs and cats in the current study areas. This study's overall gastrointestinal parasite prevalence was greater than the earlier results recorded by Contreras-Flores *et al*. (2021); Pie *et al*. (2021); Loyola-Suárez *et al*. (2019) with 19.6%, 33.3% and 39% prevalence, respectively. Similarly, higher prevalence was recorded in cats compared to the observations reported by Jittapalapong *et al*. (2007); Palmer *et al*. (2010) and Lorenzini *et al*. (2007) with 11.9%, 18.4% and 20.5% prevalence, respectively.

However, the total prevalence rate found in this investigation is generally lower than the results indicated by Teshager *et al*. (2023); Houda *et al*. (2022); Mitiku *et al*. (2020); Yimer *et al*. (2019); Octavius *et al*. (2019); Amapu *et al*. (2019) and Tolera and Berhanu (2015) for dogs and by Nateneal *et al*. (2015); Hussam (2015); Pereira *et al*. (2017) and Mohmad *et al*. (2020) and Ibrahim *et al*. (2022) for cats. Variations in climate, animal care, sampling procedures, demographics, anthelmintic use, and diagnostic methods may be the cause of these discrepancies in the prevalence of gastrointestinal parasites in dogs and cats as has been suggested before (Mundim *et al*., 2007; Katagiri and Oliveira-Sequeira, 2007; Alimohammad *et al*., 2011).

Infection with a single parasite species appears to be much more common compared to mixed infections in both cats and dogs. This is consistent with the previous findings of Teshager *et al*. (2023) in dogs in Hawassa and Nateneal *et al*. (2015) in cats of Harar town of Ethiopia. Similar observations have been documented by many other previous studies (Mitiku *et al*., 2020; Houda *et al*., 2022; Cossío *et al*., 2021). On the contrary, studies in other places of Ethiopia by Dejene *et al*. (2013) and Dagmawi *et al*. (2012) on dogs and in India by Mohmad *et al*. (2020) on cats have demonstrated significant proportions of mixed species infections compared to monoinfection by a single parasite. As already explained above, levels of environmental contamination coupled with feeding and management conditions may be responsible for such variations in the composition of the parasite population. It is also possible that parasites such as some cestode and *Strongyloides* species often pass gravid segments or L1 larvae rather than eggs in faeces, reducing the probability of detecting eggs during faecal examination (Conboy, 2009; Page *et al*., 2018).

5.2. Host characteristics, animal management and study site related risk factors play significant roles

The current study's result that adult dogs had a higher prevalence of gastrointestinal parasites than puppies and young dogs is consistent with the findings of Teshager *et al*. (2023); Houda *et al*. (2022); Mitiku *et al*. (2020); Yimer *et al*. (2019); Octavius *et al*. (2019); Loyola-Suárez *et al*. (2019); Tolera and Berhanu (2015); Dejene *et al*. (2013) and Endrias *et al*. (2010). The probable reason might be that adult dogs have more opportunity to contact other dogs and contaminated environments (Dejene *et al*., 2013). Other earlier studies, however, have demonstrated that infection rates were higher in younger dogs than in adults (Amapu *et al*., 2019; Idikaa *et al*., 2017; Dagmawi *et al*., 2012). This may suggest differences in the management of the animals where the practice of regular anthelmintic medications could reduce positivity in adult dogs. Puppies, on the other hand, have the chance of infection with some common nematode species through transmamary and congenital means (Morgan *et al*., 2013) and infection could be higher until treatment is started.

On the contrary, cats less than one year old had a higher prevalence of gastrointestinal parasites. This is consistent with the findings of Oliveira-Sequeira (2002); Rubel *et al*. (2003) and Lorenzini *et al*. (2007). The higher incidence of gastrointestinal parasites in young cats is most likely caused by an undeveloped immune system or by a lack of acquired immunity. Regarding the two most prevalent parasites in cats, *Ancylostoma* and *Toxocara*, the possibility of congenital and transmamary infection may also be responsible for the higher prevalence in younger cats (Lorenzini *et al*., 2007). However, Nateneal *et al*. (2015) recorded that there is no discernible variation in the prevalence of gastrointestinal parasites between young and adult cats in Harar town.

This study revealed that the frequency of gastrointestinal parasites is much higher in female dogs and cats than in males is consistent with earlier findings in dogs (Octavius *et al*., 2019; José *et al*., 2019; Francesco *et al*., 2018; Ahmed *et al*., 2014) and cats (Nateneal *et al*., 2015; Igor Falco *et al*., 2021; Bourgoin *et al*., 2022). The higher infections in females can be explained by contacts with several males during oestrus and the pregnancy and lactation stress that might increase the incidence of infection through negatively affecting the immune system (Luis Enrique *et al*., 2018). The responsibility of bitches feeding their pups also means that they have more contact with contaminated environment while searching for food (Zhang *et al*., 2022). It can also be explained by the fact that if the females are pregnant, tissue-encysted *Ancylostoma* and *Toxocara* worms may get reactivated, and some of them become mature in the intestines to ultimately release eggs in faeces. In contradiction to this general understanding, higher prevalence of gastrointestinal parasites in male than female dogs was reported by Teshager *et al*. (2023); Contreras-Flores *et al*. (2021); Mitiku *et al*. (2020); Loyola-Suárez *et al*. (2019); Idikaa *et al*. (2017); Dagmawi *et al*. (2012) and Endrias *et al*. (2010). A similar situation was also observed in cats by Jittapalapong *et al*. (2007) and Pereira *et al*. (2017).

Dogs and cats with diarrheal faecal consistency had a much greater incidence of gastrointestinal parasites, which may indicate that these animals were afflicted with gastrointestinal parasitism-related clinical disease. This is in line with previous findings recorded by Houda *et al*. (2022); Mukutmoni *et al*. (2022) and Igor Falco *et al*. (2021). This might be because the helminth parasite in the gastrointestinal system causes inflammation and destroys the absorptive epithelium (Esonu *et al*., 2019). One of the primary clinical indicators of gastrointestinal parasites is diarrhea (Arruda *et al*., 2021).

According to the current study, giving dogs and cats raw food was substantially linked to a higher incidence of gastrointestinal parasites than giving them cooked food regularly. This agrees with the previous report of Bourgoin *et al*. (2022); Pie *et al*. (2021); Bhowmik *et al*. (2020) and Ahmed *et al*. (2014) who indicated that compared to dogs and cats fed on adequately treated or packaged feed, animals fed uncooked animal products and leftovers from homes and restaurants had a significantly increased risk of contracting gastrointestinal parasites. Additionally, Zelalem and Mekonnen (2012) showed that dogs that were provided raw feed had the highest prevalence of gastrointestinal helminths (93.7%), followed by dogs that were occasionally fed raw animal products (90.7%) and cooked feed items (37.5%). The highest prevalence of gastrointestinal parasites in dogs that were fed raw is clarified by the fact that cooking can kill or inactivate infective eggs or cysts of gastrointestinal parasites that could be transferred among dogs via feed (Ahmed *et al*., 2014).

In this regard, cooking offals and other animal products can kill cestode cysts and hence reduce the incidence of infections with such parasites. It is also possible that the practice of providing pets with cooked foods may go with avoiding contact of food materials with soil which ultimately reduces contamination by eggs of nematode parasites. This study has revealed that although all the dogs examined were owned dogs, about 64% of them were under the category of free outdoor dogs. This, coupled with the very low percentage of responders to the questionnaire survey who indicated deworming as a potential preventative measure, raises the possibility that dogs have a higher chance of exposure to feeds contaminated with soilborne parasites.

Dogs and cats with free access to the outdoor environment are significantly at higher risk of gastrointestinal parasite infection compared to those kept in the home/compound. This agrees with the reports of Francesco *et al*. (2018); Dejene *et al*. (2013) and Tolera and Berhanu (2015) for dogs as well as Bourgoin *et al*. (2022) for cats. Free-roaming pets have a preference for hunting and consuming mice, rats, insects, mollusks, poultry, migratory birds, frogs, and small mammals (Lanszki *et al*., 2016). These foods increase the likelihood that dogs and cats will come into contact with infectious parasite stages on the ground or in intermediate/paratenic hosts (e.g., snails, birds, rodents). This implies that food sources freely thrown away into the environment will have a higher chance of being contaminated with soilborne parasites, including the dominantly prevalent ascarids and hookworms of carnivores. Dogs that roam around and scavenge seem to be more likely to come into contact with contaminated environments (Inpankaew, 2007; Tolera and Berhanu, 2015). On the contrary, Yimer *et al*. (2019) indicated that dogs that shared shelter with family had the highest prevalence (86.3%) but without explaining the conditions that contributed to the finding.

In this study, the lowest prevalence of gastrointestinal parasites of dogs was observed significantly in Bishoftu town. Such variation could be credited to the relatively higher knowledge and attitude of animal owners of the town (based on the current mean score level) towards pets' gastrointestinal parasites and the proximity of the veterinary teaching hospital of the College of Veterinary Medicine of Addis Ababa University for deworming service.

5.3. Ascarids and hookworms are major causes of gastrointestinal parasitism in dogs

Ancylostoma spp. and *Toxocara canis* were common parasites detected in dogs, which agrees with available research reports from Ethiopia and other parts of the world (Martínez *et al*., 2008; Riggio *et al*., 2013; Getachew *et al*., 2015; Tolera and Berhanu, 2015; Yimer *et al*., 2019; Octavius *et al*., 2019; Contreras-Flores *et al*., 2021; Teshager *et al*., 2023). These findings can easily be explained by the lack of health control measures, including the absence of deworming practices and poor hygienic conditions (Palmer *et al*., 2008; Raza *et al*., 2018). The dominance of these parasites is expected due to their very high fecundity that allows easy contamination of the environment. In this regard, this study has also demonstrated that *Toxocara* was the most prolific nematode parasite, followed by *Physaloptera* and *Ancylostoma* species. The ability of the parasites to pass from generation to generation through transplacental and transmamary routes (Burke and Roberson, 1985) might have also contributed to the high prevalence. A study by Morgan *et al*. (2013) has demonstrated that a female of *Toxocara* species produces an average of 12500 eggs per day, the range being 9500-55000. Specifically, the presence of the free-roaming dogs and daily discharge of *Toxocara* eggs in the environment (about 200,000 eggs/day) can create a favourable ground for persistence of infection (Despommier, 2003). Morgan *et al*. (2013) assumed that the number of eggs released into the environment is proportionate to the probability of infection with *Toxocara* spp. Accordingly, they calculated that an infected dog may contaminate the environment with about $34x10^6$ *Toxocara* eggs/ km^2 of an area.

Looking at the high prevalence of the parasites in adults than younger dogs, infections with the two most prevalent parasites might be more soilborne, although one cannot rule out other means of transmission. This argument is supported by the fact that less than 7% of questionnaire survey respondents have mentioned deworming as a means of parasite control and more than 20% of the respondents allow their dogs to scavenge and reported not to have access to veterinary services, altogether suggesting dogs' free exposure to a parasite-contaminated environment. *Toxocara canis* eggs also have a very thick cover that provides superior resistance against environmental factors (Martínez *et al*., 2008), increasing contamination risks.

Among the cestode parasites, *Dipylidium caninum* eggs were the most prevalent compared to *Taenia*/*Echinococcus* species, suggesting the dominance of infection acquired from the environment rather than through consumption of raw animal products such as offals. This agrees with the reports of Contreras-Flores *et al*. (2021) in Mexico and Teshager *et al*. (2023) in Hawassa town while other researchers have reported either lower prevalence (Tamerat *et al*., 2015; Houda *et al*., 2022) or higher prevalences (Tolera and Berhanu 2015; Getachew *et al*., 2015; Octavius *et al*., 2019; Mitiku *et al*., 2020; Amapu *et al*., 2019). Variations in the study population, the diagnostic methods employed, and the agroecological elements influencing the distribution of flea intermediate hosts may all contribute to this difference. For instance, clusters of *Dipylidium* eggs are often found attached to the perineal area (Urquhart *et al*., 1996), and hence the way samples are taken may affect the detection level of the infection. *Dipylidium* is a flea-borne parasite. Fleas are infected by ingesting eggs derived from either gravid segments discharged in faeces or eggs from degenerated segments within the intestine. When animals accidentally consume infected fleas that are infesting their bodies, they get afflicted (Rousseau *et al*., 2022). The relatively low prevalence of cestode parasites as compared to the dominant nematodes in this study could be attributed to low level of infected offals consumed. The other possible reason for the low prevalence could be the fact that the genital pore of the intact gravid segment is closed, preventing free shedding of eggs within the digestive system (Urquhart *et al*., 1996).

Giardia, though with a very low rate, was among the most prevalent protozoan parasites detected in dogs. Compared to the current finding, relatively lower prevalence was reported in Egypt (Ahmed *et al*., 2014), while higher values were recorded in Wondo Genet town of Ethiopia (Octavius *et al*., 2019), Nigeria (Amapu *et al*., 2019) and Morocco (Houda *et al*., 2022). Although there is still much to learn about the zoonotic potential of canine giardiasis (Traub *et al*., 2005), dogs and cats can carry strains of *Giardia* that could infect humans, so the zoonotic potential needs to be taken into account, particularly for those with weakened immune systems (Robertson and Thompson, 2002).

5.4. Ascarid and cestode species dominate in cats

The current study demonstrated that ascarid and cestode species of gastrointestinal parasites predominantly affect cats compared to other groups of worms. Up on morphological assessment, ascarid eggs observed were elliptical, dark brownish and had slightly pitted shell containing single cell suggesting that they belong to *Toxocara cati* and not to *Toxoascaris leonina* which are smooth shelled and lighter in colour (Cruthers *et al*., 2019). The most prevalent parasite in the cestode group was *Dipylidium caninum*, eggs of which were observed in clusters, followed by *Taeniid* groups of cestodes. The fact that ascarid eggs are highly resistant to environmental changes owing to their thick shells allows them to persist in the environment for months and years (Urquhart *et al*., 1996) and hence could be a possible reason for the dominance of the infection in cats. Similarly, *Dipylidium* infections are transmitted through fleas, which are cosmopolitan intermediate hosts of the parasite (Urquhart *et al*., 1996). The fleas *Ctenocephalides felis* was widely prevalent in cats sampled from Hawassa and Bishoftu towns of Ethiopia (Kumsa and Mekonnen, 2011). Contrary to this observation, Adhikari *et al*. (2023), in their study on cats in Nepal reported that *Toxocara cati* was less prevalent than *Ancylostoma* species, while *Dipylidium caninum* was less common than *Taeniid* group of cestodes. However, Joffe *et al*. (2011) reported that *Ascarid* parasites were much more common in cats, while *Giardia* and ascarids were dominant in dogs. Similarly, Soe *et al*. (2023) have shown that *Dipylidium caninum* and *Ancylostoma* species were more important than *Taenia* and *Toxocara* species, respectively. Such variations could be attributed to differences in the management of the animals and/or ecological diversity, which may affect the survival of parasitic eggs in the environment.

5.5. Public health risks of dog and cats' helminth parasites

Several parasites with possible zoonotic significance were identified based on egg shape. Due to their playing behavior and closeness to pets like dogs and cats, children are particularly susceptible to contracting the zoonotic parasite *Dipylidium caninum* by inadvertently consuming infected fleas (Jiang *et al*., 2017). Additionally, dogs and cats may harbour human-infectious forms of *Giardia* (Robertson and Thompson, 2002; Godínez-Galaz *et al*., 2019). Similarly, *Isospora* species are known to cause intestinal infections (Fenollar, 2017), *Ancylostoma caninum* can cause cutaneous larval migrants (Mahdy *et al*., 2012), accidental ingestion of *Toxocara* eggs or paratenic hosts harbouring larvae of the parasite may result in inflammatory reactions by encysting in different tissues (Xu and Han, 2024) in human. This strongly implies that the health management of dogs and cats can significantly reduce risks of human infections by these parasites and other infectious agents.

5.6. Knowledge, attitude and practices of dog and cat owners towards dog and cat gastrointestinal parasitism

In the current survey, the majority of the respondents were dog owners, males and within the age range of 31-50 years. Urgel *et al*. (2023) in the Philippines recorded that most respondents (dog owners) were female with the age range of 18-24 years old. A study conducted in Western Ethiopia by Yobsan *et al*. (2022) indicated that 54.6% of the study participants were females and 67.1% of them were dog owners. Similarly, a study conducted in Brazil by Arruda *et al*. (2022) revealed that more dog owners than cat owners were interviewed. Other studies carried out in nations like Canada, Italy, and Portugal have noted this tendency (Lima *et al*., 2010; Stull *et al*., 2012; Zanzani *et al*., 2014; Cardoso *et al*., 2016; Neto and Coelho, 2016; Oliveira-Neto *et al*., 2018). The greater adherence of dog owners to epidemiological and community-based studies may have been caused by many variables, including the numerical superiority of urban canine populations and their higher prevalence as companion animals (Arruda *et al*., 2022).

The majority of the respondents in the current study kept dogs and cats for more than three years for guarding purposes and as companion animals. This agrees with Mitiku *et al*. (2020), who stated that 90% of respondents in Bishoftu kept dogs to protect them from wildlife and thieves, while the remaining 10% kept dogs for companionship. On the contrary, Dejene *et al*. (2013) and Nateneal *et al*. (2015) recorded that less than 11% and 34% of the dog owners in Hawassa and Harrar towns, respectively, kept dogs for companionship and guarding purposes. According to Endrias *et al*. (2010), 8.6% and 48.6% of the respondents of Ambo town were keeping dogs for companionship and for guarding purposes, respectively. Whereas a study in Wondo Genet by Octavius *et al*. (2019) indicated that 82% of the respondents were keeping dogs to look after livestock.

The majority of the respondents in this survey had an awareness of what gastrointestinal parasites are and they knew that dogs and cats can have gastrointestinal parasites. *Ascarids* and *Cestodes* were the main parasites mentioned by the dog and cat owners. This finding is in line with the report of Mitiku *et al*. (2020) that 73.6% of the respondents knew that dogs could have gastrointestinal parasites. However, Tu *et al*. (2021) in Australia recorded that 3.8% of dog owners had the awareness that parasites can affect dogs. To a higher level than the current survey, Nigatu (2019) and Octavius *et al*. (2019) from Ethiopia revealed that *Taenia* spp. and *Toxocara canis* were mentioned as the main parasites of dogs.

The current survey revealed that the majority of the respondents knew the clinical signs of gastrointestinal parasite infection in dogs and cats, and diarrhoea, vomiting, weight loss and inappetence were mentioned by the respondents as main clinical signs. According to Urgel *et al*. (2023), the majority of respondents indicated that intestinal parasites in dogs can result in vomiting, diarrhea, and weight loss. In dogs, gastrointestinal parasites are linked to vomiting, diarrhea and weight loss (Traub *et al*., 2014; Ribeiro *et al*., 2022).

The majority of the respondents indicated that pet ownership can have health risks and they were aware of dog and cat gastrointestinal parasitic zoonosis. This finding is in line with the report of Urgel *et al*. (2023) that the majority of the respondents knew that gastrointestinal parasites can be transmitted to humans. Similarly, Arruda *et al*. (2022) indicated that a pet can pass worms to dog and cat owners with a proportion of 68.3% and 31.7%, respectively. As reported by Endrias *et al*. (2010), 44.3% of dog owners were aware that dogs may spread diseases to people. Dogs living together, playing with dogs, poor management practices, dog owners' ignorance about dog parasites, and a lack of veterinary care can all increase the danger of spreading canine parasitic zoonoses to the human population (Endrias *et al*., 2010). Whereas Dagmawi *et al*. (2012) recorded that 8.8% of respondents knew that owning dogs in close proximity poses a risk to public health, and Nateneal *et al*. (2015) found that 72.9% of respondents were unaware of parasitic zoonotic infections in pets in Harrar town.

It is quite challenging to describe pet management practices in Ethiopia, mostly because they are not strictly regulated by cleanliness standards. This suggests that there is a very high chance that people will contract zoonotic diseases linked to pet contact. Furthermore, letting dogs run loose in the living room and outside might encourage the transmission of diseases linked to pets (Larry *et al*., 2008).

In the current survey, the majority of the dog and cat owners kept their dog/cat free outdoors. This is in line with the report of Endrias *et al*. (2010) that 78.6% of the dogs were free (both indoor and outdoor systems) and only 12.4% were kept confined indoors. Similarly, Dejene *et al*. (2013) recorded that 19.5% of the owners had the experience of keeping their dogs confined (indoor), whereas 36.4% and 42.9% of them kept their dogs outdoors and semi-confined, respectively. To the contrary, Octavius *et al*. (2019) indicated that 100% of the dog owners shared the same house with their dogs and livestock, and Yobsan *et al*. (2022) showed that the majority (39.6%) of the participants shared a living room with their pet.

Regarding with feeding practices, there is a significant zoonotic danger associated with the growing popularity of raw feed for companion animals. It has been discovered that these diets and their components include harmful microbes (Larry *et al*., 2008). In the current survey, most respondents fed their dog and cat raw offal/meat/milk, followed by scavenging, condemned offal and human food, and cooked offal/meat/milk. This finding is in line with the report of Dejene *et al*. (2013) that respondents fed their dogs raw animal products (12.9%), cooked animal products (2.6%), household leftovers and mix of raw animal products (58.4%) and household leftovers (25.9%). Similarly, Octavius *et al*. (2019) indicated that dog owners fed their dogs condemned offals (56%) and condemned offals and human food (44%). Likewise, Mitiku *et al*. (2020) revealed that 83.7% of dog owners either fed their dogs uncooked offal from butcher houses or backyard slaughter or released them to search for their feed.

In the current survey, the majority of the dog and cat owners had experience of cleaning pets' excrement and disposing it into the toilet using the necessary protective equipment. To the contrary, Endrias *et al*. (2010) recorded that only 11.4% of the households disposed of dogs' faeces into their toilets and none of the individuals cleaning the kennels were taking the necessary precautions. Whereas Mitiku *et al*. (2020) revealed that 47.9% of the owners disposed of dogs' faeces with household garbage out of their compound and 88.6% of the dog owners cleaned and disposed of the excreta without using necessary precautions for personal protection. Preventing the spread of gastrointestinal parasites can be greatly aided by owners who routinely clean the places, especially those contaminated with faeces (Kohansal *et al*., 2017). In general, minimizing environmental contamination and the danger of zoonotic transmission involves the practice of appropriately disposing of animal waste and cleaning it off the ground afterward (Contreras-Flores *et al*., 2021).

Regarding getting access to veterinary services in the current study, 49.3% of the respondents had accessed veterinary services and only 22.1% of them had a deworming service. Surveys by Yobsan *et al*. (2022) and Nigatu (2019) revealed that the respondents had not accessed regular veterinary services for their cat and/or dog, with proportions of 64.2% and 61%, respectively. Every three to six months, deworming is advised as a crucial preventative measure against gastrointestinal parasites (Traversa, 2012). Deworming dogs more frequently than every six months increases their risk of contracting gastrointestinal parasites (Palmer *et al.*, 2010). According to Mitiku *et al*. (2020) and Dagmawi *et al*. (2012), the proportion of respondents who had deworming services was 58.6% and 7.4%, respectively. The risk of gastrointestinal parasites to the general population is increased when dogs and cats receive inadequate veterinary care. In the current survey, even though the respondents had good knowledge and positive attitude, they had poor practices. This could be due to the fact that there is a shortage of veterinary services with affordable prices in the study areas. In general, the owner's management and deworming practices can have an impact on gastrointestinal parasite infections in dogs and cats (Urgel *et al*., 2019).

Among the respondents in this survey, the majority of them had no usual contact with their dog and cat and had no experience of consuming raw meat/vegetables. To the contrary, Nateneal *et al*. (2015) indicated that 82.9% of the respondents had physical contact with their dog and cat, and Nigatu (2019) and Octavius *et al*. (2019) recorded that children play with dogs with proportions of 90.2% and 100%, respectively. The majority of the respondents in this survey thought that feeding raw food to dogs and cats can cause gastrointestinal parasitosis. In this regard, Arruda *et al*. (2022) from Brazil recorded that 66.7% of dog owners and 33.3% of cat owners served raw or undercooked meat for their dog or cat. The majority of dog and cat owners indicated hygienic practices and habits that are thought to be protective against intestinal parasites. These include correctly disposing of animal waste, eating well-cooked meat, and cleaning fruits and vegetables before eating them (Arruda *et al*., 2022). This collection of activities is crucial from the standpoint of One Health since it can help stop the spread of zoonotic parasites from animals to people (Loss *et al*., 2012; Cardoso *et al*., 2016).

5.7. Limitations of the study

Based on the available literature so far, this is the first study and document dealing with gastrointestinal parasites of dogs and cats (both at the same time) in the current study areas, along with the assessment of knowledge, attitude and practices of the dog and cat owners toward gastrointestinal parasites of dogs and cats. Despite the above fact, mainly because of financial and resource constraints, the limitations of this study is related with issues that confirmatory molecular tests were not used for further identification of gastrointestinal parasites of dogs and cats, and because of those constraints study areas from lowland agro-ecology, stray dogs and wild carnivores were not able to be considered in this study.

6. CONCLUSION AND RECOMMENDATIONS

The current study demonstrated a high overall prevalence of gastrointestinal parasites in dogs and cats. Nematode parasites have the largest share in the monoparasite species infection in dogs and cats. Significantly the highest prevalence of gastrointestinal parasites of dogs was observed in Dukem. Likewise, a significantly higher prevalence of gastrointestinal parasites in female dogs and cats, in adult dogs and in young cats was observed. Housing conditions in dogs and feeding conditions in dogs and cats in this study had a significant impact on the prevalence of gastrointestinal parasites. Dogs housed free outdoors and dogs and cats that were fed uncooked food had a significantly higher prevalence of gastrointestinal parasites. Hence, the current study demonstrated that study site, sex, age, housing condition and feeding condition were the potential risk factors that had significant association with the prevalence of gastrointestinal parasites in dogs and/or cats. The current study indicated that *Ancylostoma* spp. was the most common parasite detected in dogs, followed by *Toxocara canis* and *Dipylidium caninum*. Whereas *Toxocara cati* was the most common parasite in cats, followed by *Dipylidium caninum* and *Taenia* spp. This indicates that gastrointestinal parasite infection is still prevalent enough to affect dogs and cats in the study areas, causing mortality and morbidity in these animals. The parasitic infections in dogs and cats of the current study areas can be a significant public health concern, so the One Health approach is essential to tackle this public health threat. The current questionnaire survey has revealed that most of the respondents knew that dogs and cats can acquire gastrointestinal parasites and some of these gastrointestinal parasites of dogs and cats can be transmitted to humans. Majority of the respondents were found to think that dog and cat ownership can have health risks and medication/treatment is necessary when dogs and cats experience gastrointestinal parasitosis. It was discovered that it was a widespread practice to feed dogs and cats uncooked condemned offal, which could lead to the development of a favourable environment for the completion of the life cycle of zoonotic gastrointestinal parasites. Generally, the present questionnaire survey disclosed that dog and cat owners had good knowledge, positive attitude and poor practices regarding gastrointestinal parasites of dog and cat. Finally, effective prevention and control of gastrointestinal parasites in dogs and cats require improved practices of pet owners about the health impact of those parasites in animals and humans.

Based on the above conclusion, the following recommendations are forwarded:

- Strategic control and prevention methods should be put in place in the study areas, including periodic deworming of dogs and cats using broad-spectrum anthelmintics.
- The public health sector of the study areas should initiate a study on the health impact of gastrointestinal parasites of dogs and cats by doing health surveillance in animal owners for any associated zoonosis caused by the gastrointestinal parasites to formulate guidelines for the prevention and control of these parasites.
- Dog and cat owners should implement good practices by providing appropriate shelter, food and regular deworming services for their animals, and they should remain up to date with the latest knowledge and products for gastrointestinal parasite prevention and control with the help of health professionals.
- Health education on the zoonotic significance of gastrointestinal parasites of dogs and cats should be given to animal owners who had awareness limitations about pets' gastrointestinal parasites and maintenance of environmental hygiene should be introduced by the concerned body.
- Due to budget and laboratory facility limitations, molecular techniques were not used in the present study. Therefore, further in-depth epidemiological and molecular investigation to identify gastrointestinal parasites of dogs and cats to the species level covering larger study areas of central Ethiopia, including lowland agroecology and different seasons, shall be conducted to fully understand their economic and zoonotic impact.
- Appropriate investigation on the status of gastrointestinal parasites in humans and in the environment should be conducted using the One Health approach by performing epidemiological studies on canine and feline zoonotic gastrointestinal parasites for effective control of these parasites.
- A detailed assessment of the practice and management gap of animal owners regarding gastrointestinal parasites of dogs and cats shall be conducted, and appropriate corrective measures shall be carried out, including creating access to affordable veterinary services in the study areas.
- It is crucial to make a comprehensive epidemiological survey on gastrointestinal parasites in stray dogs and wild carnivores using advanced diagnostic techniques to set appropriate control measures for these parasites.

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8. APPENDICES

Appendix 1. Record Format for Basic Data During Faecal Sample Collection

Date	ID of Animal	Species of Animal	Origin	Sex	Age	Breed	Feeding condition (cooked/uncooked)	Housing condition	Faecal consistency	Remark (adult parasite, …)

Appendix 2. Record Format for Laboratory Result

Date	ID of Animal	Species of Animal	Origin	Sex	Age	Breed	Any Detected GIT Parasites

Appendix 3: Questionnaire survey to assess knowledge, attitude and practices of dog and cat owners toward dog and cat gastrointestinal parasites and their zoonotic impacts in selected districts of central Ethiopia

Part I: Participant information sheet/Information about the research (English, Amharic and Afaan Oromoo version)

Hello, my name is Kibruyesfa Bayou. I am a PhD postgraduate student at Addis Ababa University. Now I am conducting a study entitled: *Gastrointestinal Parasites of Dog and Cat: Epidemiology and Community Knowledge, Attitude and Practices (KAP) on the Parasites in Selected Areas of Central Ethiopia*. The study finding will give information on the prevalence, associated risk factors and KAP of dog and cat owners regarding gastrointestinal parasites of dog and cat in the study areas and this will help for intervention and control programs. You are invited to participate in this study. Please read/hear the following statements and ask for any unclear points before you agree to participate. If you agree to be included in this study, I would like to ask your confirmation to participate accordingly. Participation in this study is exclusively voluntary. If you decide to participate in this study, you are expected to give answers to some questions about your knowledge, attitude and practices regarding with gastrointestinal parasites of dog and cat. In addition, you are expected to agree on that 5-10 grams faecal sample will be collected from your dog and cat. Specimen collection will not affect and pose no pain on your dog or cat. I would like to assure you that all the results and the answers you give will be kept confidential and for the study purpose only. You have full right to stop being participant of the research study at any time without explanation. Also, you have right to ask any question about the study to be answered and I will be glad to answer your questions about this study at any time. You may contact me at email address: kibruyesfab@gmail.com or mobile: +251 912053414.

Participant information sheet/Information about the research (Amharic version)

ለተሳታፊዎች ስለ ጥናቱ መረጃ የሚሰጥ ቅጽ

ሰላም፡ ስሜ ክብሩይስፋ ባዩ ይባላል። በአዲስ አበባ ዩኒቨርሲቲ የፒ.ኤች.ዲ የድህረ ምረቃ ተማሪ ነኝ። አሁን የውሻ እና የድመት የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ዓይነት ፣ ስርጭት፣ ተያያዥ መንስኤዎች እና ጋር ከዚህ ጋር በተያያዘ የማህበረሰብ ዕውቀት፣ አመለካከት እና ተግባር በማዕከላዊ ኢትዮጵያ ሶስት የተመረጡ አካባቢዎች ጥናት እያካሄድኩ ነው። ይህም ጥገኛ ተህዋስያኑ ጋር በተያያዘ ለሚሰሩ የቁጥጥር ፕሮግራሞች ይረዳል። በዚህ ጥናት ላይ እንዲሳተፉ ተጋብዘዋል። ለመሳተፍ ከመስማማትዎ በፊት እባክዎ የሚከተሉትን መግለጫዎች ያንብቡና/ይስሙና ግልጽ ያልሆኑ ነጥቦችን ይጠይቁ። በዚህ ጥናት ውስጥ ለመሳተፍ ከወሰኑ፣ ስለ ውሻ እና ድመት የአንጀትና የጨጓራ ጥገኛ ተህዋስያን በተመለከተ ስለ እርስዎ እውቀት፣ አመለካከት እና ተግባር ለተወሰኑ ጥያቄዎች መልስ መስጠት ይጠበቅብዎታል። በተጨማሪም፣ ከ5-10 ግራም የሰገራ ናሙና ከውሻዎ ወይም ድመትዎ እንደሚሰበሰብ መስማማት ይጠበቅብዎታል። የናሙና መሰብሰቡ ሂደት በውሻዎ ወይም ድመትዎ ላይ ምንም አይነት ህመም/ጉዳት አያስከትልም። ሁሉም የጥናቱ ውጤቶች እና የሚሰጡት መልሶች በሚስጥር እና ለጥናት ዓላማ ብቻ እንደሚቀመጡ ላረጋግጥልዎ እወዳለሁ። ያለ ማብራሪያ በማንኛውም ጊዜ ከጥናቱ ተሳታፊነት ለመውጣት ሙሉ መብት አለዎት። እንዲሁም፣ ስለ ጥናቱ ጥያቄ ካለዎት በማንኛውም ጊዜ ለሚነሱ ጥያቄዎች መልስ ለመስጠት ደስተኛ ነኝ። ለዚህም በኢሜል አድራሻ፡ kibruyesfab@gmail.com ወይም ሞባይል፡ +251 912053414 ሊያገኙኝ ይችላሉ።

Participant information sheet/Information about the research (Afaan Oromoo version)

Unka odeeffannoo waa’ee qorannichaa hirmaattotaaf kennu

Akkam jirtu: Maqaan koo Kibruyisfaa Bayuu jedhama. Ani Yunivarsiitii Addis Ababaatti barataa digirii lammaffaa PhD ti. Yeroo ammaa kana gosa, raabsa, sababoota wal-qabatan ilbiisota garaachaa fi garaachaa adurree fi sareewwanii fi beekumsa hawaasaa, ilaalchaa fi gochaalee kanaan wal-qabatan irratti naannoolee filatamoo sadii giddu-galeessa Itoophiyaa keessatti qorannoo gaggeessaa jira. Kunis sagantaalee to’annoo raammoolee irratti ni gargaara. Qo’annoo kana irratti akka hirmaattan affeeramtaniittu. Hirmaachuuf walii galuu keessan dura, maaloo ibsa armaan gadii dubbisaa fi/ykn dhaggeeffadhaatii qabxiilee ifa hin taane yoo jiraatan gaafadhaa. Qorannoon kana irratti hirmaachuuf yoo murteessite, waa’ee beekumsa, ilaalchaa fi gocha kee waa’ee ilbiisota garaachaa fi garaachaa saawwanii fi adurree irratti gaaffiiwwan addaa akka deebistu si gaafatama. Dabalataanis, saamuda sagaraa giraama 5-10 ta’u saree ykn adurree keessan irraa akka sassaabamu walii galuun isin irraa eegama. Adeemsi saamuda walitti qabuu saree ykn adurree keessan irratti dhukkubbii/miidhaa tokkollee hin fidu. Bu’aan qorannoo fi deebii isin kennitan hundi iccitii ta’ee fi qorannoo qofaaf akka ta’u isin mirkaneessuu barbaada. Yeroo barbaaddetti ibsa malee qo’annoo keessaa ba’uuf mirga qabda. Akkasumas, gaaffii waa'ee qorannichaa qabdan kamiyyuu deebisuuf gammachuu guddaatu natti dhaga'ama. Kanaafis teessoo email koo: kibruyesfab@gmail.com ykn mobaayila: +251 912053414 irratti na qunnamuu dandeessu.

Part II: Informed consent form (English, Amharic and Afaan Oromoo version)

I undersigned/agreed to confirm that, I give consent to participate after a clear explanation of the objective and purpose of the study to me in the language I understand.

I____ do interestingly give consent to Mr/Dr. ______________________________to give permission faecal sample to be collected from my dog or cat and to give answers for the questionnaire-based interview.

Name of participant: _______________________________ Signature: __________

Name of data collector: _____________________________ Signature: __________

Date: ______________

Informed consent form (Amharic version)

ተሳታፊው በጥናቱ ለመሳተፍ ሙሉ ፈቃደኛ መሆኑን የሚገልጽበት ቅጽ

የተሳታፊው ስም_______________________________________ ስለጥናቱ አስፈላጊ የሆኑትን መረጃዎች አንብቤ ወይም ተነቦልኝ የጥናቱ ዐላማ እና አስፈላጊነት ተረድቻለሁ፡፡ በማንኛውም ሰዓት ከጥናቱ የመውጣት መብት እንዳለኝ ተነግሮኛል፡፡ ከጥናቱ ጋር የተያያዙ ጥያቄዎችንም ጠይቄ ማብራሪያዎች ተሰጥተዉኛል፡፡ እናም በዚህ ጥናት ለመሳተፍ ሙሉ ፍቃደኛ መሆኔን ከታች በመፈረም/በመስማማት አረጋግጣለሁ፡፡

እኔ____የተባልኩ የጥናቱ ተሳታፊ የተጠየቁትን ጥያቄዎች መልስ ለመስጠት እና ከውሻዬ ወይም ከድመቴ የሰገራ ናሙና እንዲወሰድ ፈቃደኝነቴን አረጋግጣለሁ፡፡

የተሳታፊው ፊርማ ______________________ ቀን ________________

የተመራማሪዉ ፊርማ ____________________ ቀን ________________

Informed consent form (Afaan Oromoo version)

Unka hirmaataan qo'annicha irratti hirmaachuuf fedhii akka qabu itti ibsu

Maqaa Hirmaataa____ Waa'ee qorannichaa odeeffannoo barbaachisaa ta'e dubbisee ykn dubbisee kaayyoo fi barbaachisummaa qorannichaa hubadheera. Yeroo kamitti iyyuu qo'annaa sana keessaa ba'uuf mirga akkan qabu natti himame. Akkasumas gaaffilee qorannichaan walqabatan gaafadhee ibsi naaf kennameera. Armaan gaditti mallatteessuudhaan qorannoo kana irratti hirmaachuuf fedhii guutuu akkan qabu nan mirkaneessa.

Ani, ____ hirmaataan qorannichaa, gaaffilee gaafataman deebisuuf akkasumas saamuda sagaraa saree ykn adurree koo irraa akka fudhatamu walii galuu koo mirkaneessa.

Mallattoo Hirmaataa ______________________ guyyaa ____________________

Mallattoo Qorataa _________________________ guyyaa ___________________

Part III: Questionnaire Formats (English, Amharic and Afaan Oromoo versions)

Purpose: To assess knowledge, attitude and practices of dog and cat owners toward dog and cat gastrointestinal parasites and their zoonotic impacts in selected districts of central Ethiopia

A. Animal owner demographic data and dog and cat ownership and purpose for keeping

1. Name of Head of Household/Animal owner/ ________________________________

2. Sex: A. Male B. Female

3. Full Address/District/ ____

4. How old are you? (Tick ("√") on the correct choice)

1	18-30 yrs.	
2	31-50 yrs.	
3	> 50 yrs.	

5. What is your marital status? (Tick ("√") on the correct choice)

1	Single	
2	Married	

6. What is your education level? (Tick ("√") on the correct choice)

1	Non-formal education/ Illiterate	
2	Primary school education	
3	Secondary school education	
4	College/University	

7. What is your occupation for living? (Tick ("√") on the correct choice)

1	Crop farming	
2	Livestock/poultry keeping	
3	Civil servant/ Professional	
4	Merchant	
5	Others	

8. Which type of pet do you keep/have? (Tick ("√") on the correct choice)

Dog	
Cat	

9. How long have you been keeping your dog/cat? (Tick ("√") on the correct choice)

1	Below one year	
2	Between one and three	
3	Above three years	

10. For what purpose do you keep your dog/cat? (Tick ("√") on the correct choice)

1	Guarding	
2	Chase rodents	
3	Companion	
4	Look after livestock	

B. Management and practices of dog and cat owners towards gastrointestinal parasites

1. How do you keep your dog/cat? (Tick ("√") on the correct choice)

1	Kennel/leashed	
2	Free outdoor	
3	Free in home/compound	

2. What do you feed your dog/cat? (Tick ("√") on the correct choice)

1	Cooked offal/meat/milk	
2	Raw offal/meat/milk	
3	Scavenging	
4	Condemned offals and human food	
5	Commercial feed	

3. Where is the usual place of defecation of your dog/cat? (Tick ("√") on the correct choice)

1	In public field	
2	In their cage only	
3	In the compound/ground/	

4. How do you clean and dispose your dog/cat faeces? (Tick ("√") on the correct choice)

1	Cleaning and burying in the ground	
2	Cleaning and adding to the toilet	
3	Cleaning and disposing with house garbage	
4	No cleaning	

5. Do you use protective equipments (glove, boots and coverall/gown) during cleaning? A. Yes B. No

6. Do you have access to any veterinary service for your dog/cat? A. Yes B. No

7. If yes for question 6, tick ("√") for any of the following vet. services for your dog/cat.

1	Vaccination	
2	Deworming	
3	Spaying/neutering	
4	Other services	

8. Do you (your family) have usual contact with your dog/cat? A. Yes B. No

9. Do you eat raw meat/vegetables? A. Yes B. No

10. Do you wash your hand before a meal? A. Yes B. No

C. Knowledge of dog and cat owners toward dog and cat gastrointestinal parasites and their zoonotic importance

1. Do you know what gastrointestinal parasites are? A. Yes B. No
2. Do you know that dogs/cats can have gastrointestinal parasites? A. Yes B. No
3. Do you know any gastrointestinal parasites of dogs/cats? A. Yes B. No
4. If yes for question 3, mention some parasites ______________________________________

____

5. Do you know any clinical sign of gastrointestinal parasites infection in dogs/cats?

   A. Yes B. No

6. If yes for question 5, mention main clinical signs ___________________________________

____

7. Do you know the mode of transmission of gastrointestinal parasites from animal to animal?

A. Yes B. No

8. If yes for question 7, mention main modes of transmission ___________________________

____

9. Do you know how to control/prevent gastrointestinal parasites in dogs and cats?

   A. Yes B. No

10. If yes for question 9, mention main mechanisms to control/prevent the parasites _______

____

11. Did you observe a parasite or a segment of parasite in your dog/cat faeces?

   A. Yes B. No

12. Do you know any gastrointestinal parasite of dogs/cats that can be transmitted to humans?

A. Yes B. No

13. If yes for question 12, mention main parasites ____________________________________

____

14. Do you know the mode of transmission of gastrointestinal parasites from dogs/cats to man? A. Yes B. No

15. If yes for question 14, mention main modes of transmission _________________________

____

D. Attitude of dog and cat owners toward dog and cat gastrointestinal parasites and their zoonotic importance

1. Do you think gastrointestinal parasitosis is a serious disease? A. Yes B. No
2. Do you think pet ownership can have health risk? A. Yes B. No
3. Do you think playing/contact with dog/cat may expose you to gastrointestinal parasitosis? A. Yes B. No
4. Do you think feeding raw food to dog/cat can cause gastrointestinal parasitosis? A. Yes B. No
5. Do you think washing hands appropriately may hinder the transmission of gastrointestinal parasites to humans? A. Yes B. No
6. Do you think medication/treatment is necessary when your dog/cat experience gastrointestinal parasitosis? A. Yes B. No
7. Do you think health education can reduce gastrointestinal parasite prevalence? A. Yes B. No

Questionnaire (Amharic version)

የጥናቱ ኣላማ: በቢሾፍቱ፣ በዱከምና በአዲስ አበባ የሚገኙ የውሻ እና የድመት ባለቤቶች ከውሻ እና ድመት የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ጋር በተያያዘ ያላቸውን እውቀት፣ አመለካከት/እምነት እና ተግባር ለማወቅ ነው፡፡

ክፍል አንድ: የእንስሳት ባለቤት ማህበራዊ ና ግለ-ታሪክ ፣ የውሻ እና የድመት ባለቤትነት እና የማቆየት ዓላማ

1. የእንስሳት ባለቤት ስም: ___________________________

2. ፆታ: 1. ወንድ 2. ሴት

3. ሙሉ አድራሻ: ___________________________

4. ዕድሜ ("√" ምልክት ያድርጉ)

1	18-30 አመት	
2	31-50 አመት	
3	> 50 አመት	

5. የትዳር ሁኔታ ("√" ምልክት ያድርጉ)

1	ያላገባ (ች)	
2	ያገባ (ች)	

6. የትምህርት ሁኔታ ("√" ምልክት ያድርጉ)

1	መደበኛ ያልሆነ ትምህርት የተማረ/ያልተማረ	
2	የመጀመሪያ ደረጃ ትምህርት (1-8)	
3	ሁለተኛ ደረጃ (9-12)	
4	ኮሌጅ / ዩኒቨርሲቲ	

7. የስራ ሁኔታ ("√" ምልክት ያድርጉ)

1	እርሻ	
2	የእንስሳት / የዶሮ እርባታ	
3	የመንግስት ሰራተኛ / ባለሙያ	
4	ነጋዴ	
5	ሌሎች	

8. የትኛው የቤት እንስሳ ነው ያለዎት? ("√" ምልክት ያድርጉ)

ውሻ	
ድመት	

9. ውሻዎን/ድመትዎን ለምን ያህል ጊዜ አኑረዋል? ("√" ምልክት ያድርጉ)

1	< 1 አመት	
2	1-3 አመት	
3	> 3 አመት	

10. ለምንድነው ውሻ/ድመት የሚያኖሩት? ("√" ምልክት ያድርጉ)

1	ለጥበቃ	
2	አይጥን ለመከላከል	
3	ለጉዋደኝነት	
4	የቤት እንስሳትን ለመጠበቅ	

ክፍል ሁለት: የውሻ እና የድመት ባለቤቶች አስተዳደር እና ልምዶች ከ አንጀትና የጨጓራ ጥገኛ ተህዋስያን ጋር በተያያዘ

1. ውሻዎን/ድመትዎን እንዴት ይጠብቃሉ/ያኖራሉ? ("√" ምልክት ያድርጉ)

1	በውሻ/ድመት ቤት ውስጥ በማኖር	
2	ከግቢ/ቤት ውጪ ነጻ ዝውውር እንዲያደርጉ በመፍቀድ	
3	በግቢ/ቤት ውስጥ በነፃነት መዘዋወር/መኖር	

2. ውሻዎን/ድመትዎን ምን ይመግባሉ? ("√" ምልክት ያድርጉ)

1	የተቀቀለ የእንስሳት የሆድ ዕቃ/ስጋ/ወተት	
2	ጥሬ የእንስሳት የሆድ ዕቃ/ስጋ/ወተት	
3	ምግብ ፈልገዉ እንዲመገቡ በማድረግ	
4	የእንስሳት የሆድ ዕቃ እና የሰው ምግብ	
5	የፋብሪካ ምግብ	

3. የተለመደው የውሻዎ/ድመት መጸዳጃ ቦታ የት ነው? ("√" ምልክት ያድርጉ)

1	በሕዝብ ሜዳ	
2	በቤታቸው ውስጥ ብቻ	
3	በግቢው/መሬት ውስጥ/	

4. የውሻዎን/የድመትን ሰገራ እንዴት ያፀዳሉ/ያስወግዳሉ? ("√" ምልክት ያድርጉ)

1	ማፀዳትና መሬት ውስጥ መቅበር	
2	ማጽዳት እና ወደ መጸዳጃ ቤት መጨመር	
3	ማጽዳት እና ከቤት ውስጥ ቆሻሻ ጋር ማስወገድ	
4	አይፀዳም	

5. በማጽዳት ጊዜ መከላከያ መሳሪያዎችን (ጓንት፣ የፊት ጭንብል፣ ቦት ጫማ እና/ወይም ሽፋን/ጋውን) ይጠቀማሉ?

1. አዎ 2. አልጠቀምም

6. ለውሻዎ/ድመትዎ የህክምና አገልግሎት ያገኛሉ? 1. አዎ 2. አላገኝም

7. ለጥያቄ 6 መልሱ አዎ ከሆነ፣ ውሻዎ/ድመትዎ ከሚከተሉት የእንስሳት ሕክምና አገልግሎቶች ውስጥ የትኛውን አግኝተዋል? ("√" ምልክት ያድርጉ)

1	ክትባት	
2	ፀረ-የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ህክምና	
3	ማኮላሸት	
4	ሌሎች	

8. እርስዎ (ቤተሰብዎ) ከውሻዎ/ድመትዎ ጋር የተለመደ ንክኪ አሎት? 1. አዎ 2. የለኝም

9. እርስዎ ጥሬ ሥጋ/አትክልት ይመገባሉ? 1. አዎ 2. አልመገብም

10. ምግብ ከመመገብዎ በፊት እጅዎን ይታጠባሉ? 1. አዎ 2. አልታጠብም

ክፍል ሶስት: የውሻ እና የድመት ባለቤቶች እውቀት ስለ ውሻ እና ድመት የአንጀትና የጨጓራ ተህዋስያን እና እነሱ ሰው ላይ ስለሚያመጡት የጤና ችግር

1. የአንጀትና የጨጓራ ተህዋስያን ምን እንደሆኑ ያውቃሉ? 1. አዎ 2. አላውቅም

2. ውሾች/ድመቶች የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ሊኖራቸው እንደሚችል ያውቃሉ? 1. አዎ 2. አላውቅም

3. የውሾች/ድመቶች የአንጀትና የጨጓራ ጥገኛ ተውሳኮችን ያውቃሉ? 1. አዎ 2. አላውቅም

4. ለጥያቄ 3 መልሱ አዎ ከሆነ፣ ዋና ዋና ጥገኛ ተውሳኮችን ይጥቀሱ ____

____

5. በውሻ/ድመቶች ላይ የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ክሊኒካዊ ምልክት ያውቃሉ? 1. አዎ 2. አላውቅም

6. ለጥያቄ 5 መልሱ አዎ ከሆነ፣ ዋና ዋና ክሊኒካዊ ምልክቶችን ይጥቀሱ ____

7. የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ከእንስሳ ወደ እንስሳ የሚተላለፉበትን ዘዴ ያውቃሉ? 1. አዎ 2. አላውቅም

8. ለጥያቄ 7 መልሱ አዎ ከሆነ፣ ዋና ዋና የመተላለፊያ ዘዴዎችን ይጥቀሱ ____

____

9. የውሻ እና የድመቶችን የሆድ ውስጥ ጥገኛ ተውሳኮችን እንዴት መቆጣጠር/መከላከል እንደሚቻል ያውቃሉ?

1. አዎ 2. አላውቅም

10. ለጥያቄ 9 መልሱ አዎ ከሆነ፣ ጥገኛ ተሕዋስያንን ለመቆጣጠር/ለመከላከል ዋና ዘዴዎችን ይጥቀሱ _____________________

____

11. በውሻዎ/ድመትዎ ሰገራ ውስጥ ጥገኛ ተውሳክ ወይም የተህዋሲያን ክፍል ተመልክተዋል? 1. አዎ 2. አላውቅም

12. ወደ ሰው ሊተላለፍ የሚችል የውሾች/ድመቶች የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ያውቃሉ?

1. አዎ 2. አላውቅም

13. ለጥያቄ 12 መልሱ አዎ ከሆነ፣ ዋና ዋና ጥገኛ ተህዋስያን ይጥቀሱ ____

14. የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ከውሾች/ድመቶች ወደ ሰው የሚተላለፉበትን ዘዴ ያውቃሉ?

1. አዎ 2. አላውቅም

15. ለጥያቄ 14 መልሱ አዎ ከሆነ፣ ዋና ዋና የመተላለፊያ መንገዶችን ይጥቀሱ ______________________________________

ክፍል አራት: የውሻ እና የድመት ባለቤቶች አመለካከት ስለ ውሻ እና ድመት የአንጀትና የጨጓራ ተህዋስያን እና እነሱ ሰው ላይ ስለሚያመጡት የጤና ችግር

1. የአንጀትና የጨጓራ ጥገኛ ተህዋስያን በሽታ ከባድ በሽታ ነው ብለው ያስባሉ? 1. አዎ 2. አላስብም

2. የውሻ/ድመት ባለቤትነት ጤናን አደጋ ላይ ሊጥል ይችላል ብለው ያስባሉ? 1. አዎ 2. አላስብም

3. ከውሻ/ድመት ጋር መጫወት/መነካካት ለአንጀትና የጨጓራ ጥገኛ ተህዋስያን በሽታ ሊያጋልጥ ይችላል ብለው ያስባሉ?

1. አዎ 2. አላስብም

4. ጥሬ ምግብን ለውሻ/ድመት መመገብ የአንጀትና የጨጓራ በሽታ አምጪ ተሕዋስያን ሊያስከትል ይችላል ብለው ያስባሉ?

1. አዎ 2. አላስብም

5. እጅን በአግባቡ መታጠብ የአንጀትና የጨጓራ ጥገኛ ተህዋስያን ወደ ሰዎች እንዳይተላለፉ ለማድረግ ይረዳል ብለው ያስባሉ?

1. አዎ 2. አላስብም

6. ውሻ/ድመት በአንጀትና የጨጓራ ጥገኛ ተህዋስያን በሽታ ከተጠቁ ሕክም ማድረግ ያስፈልጋቸዋል ብለው ያስባሉ?

1. አዎ 2. አላስብም

7. የጤና ትምህርት የአንጀትና የጨጓራ ጥገኛ ተህዋስያንን ስርጭት ሊቀንስ ይችላል ብለው ያስባሉ?

1. አዎ 2. አላስብም

Questionnaire (Afaan Oromoo version)

Kaayyyoon qorannichaa: beekumsa, ilaalcha/amantaa fi gocha abbootii qabeenyaa saree fi adurree Bischoftu, Duqem fi Addis Ababa keessatti raammoolee garaachaa fi garaachaa saree fi adurree wajjin walqabatee jiru baruuf

Kutaa tokkoffaa: Daataa dimogiraafii Abbaa Beeyladotaa fi Abbummaa fi kaayyoo saree fi adurree eeguu

1. Maqaa Itti Gaafatamaa Maatii/Abbaa Beeyladaa/:___________________________________

2. Saala: 1. Dhiira 2. Dubartii

3. Teessoo/Aanaa Guutuu: ____

4. Umriin keessan meeqa? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	18-30	
2	31-50	
3	> 50	

5. Haalli gaa'ela keessanii maali? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Kan hin fuune	
2	Kan fuudhe	

6. Sadarkaan barnootaa keessan maali? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Barnoota idilee hin taane/ Dubbisuu fi barreessuu kan hin dandeenye	
2	Mana barumsaa sadarkaa tokkoffaa	
3	Barnoota sadarkaa lammaffaa	
4	Kolleejjii/Yuunivarsiitii	

7. Hojiin keessan maali? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Qonna midhaanii	
2	Horsiisa beeyladaa/Horsiisa lukku	
3	Hojjetaa mootummaa/ Ogeessa	
4	Daldalaa	
5	Kan biroo	

8. Gosa bineensa manaa kam qabdu? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

Saree	
Adurree	

9. Yeroo hangamiif saree/adurree keessan eegdan? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	< waggaa 1	
2	Waggaa 1-3	
3	> Waggaa 3	

10. Kaayyoon keessan saree/adurree kana eeguuf maali? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Hanna irraa eeguu	
2	Hantuuta ittisuuf	
3	Hiriyummaa	
4	Beeylada eeguu	

Kutaa Lammaffaa: Bulchiinsa fi gocha abbootii qabeenyaa saree fi adurree raammoolee garachaa irratti

1. Akkamitti saree/adurree keessan eegdan? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Mana saree/adurree	
2	Mooraan ala bahe/akka fedhetti mooraa keessa bahe fi deebié jiraatu	
3	Mana/mooraa keessatti bilisa	

2. Saree/adurree keessan maal nyaachiftu? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Mi'a garaa keessaa /foon bilcheefame/Aannan	
2	Mi'a garaa keessaa/foon qalamaa/Aannan	
3	Nyaata barbaadee nyaachuu	
4	Mi'a garaa keessaa fi nyaata namaa irraa hafe	
5	Nyaata daldalaa	

3. Saree/adurreen keessan eessatti bobaa gooti? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Dirree ummataa keessatti	
2	Godoo isaanii qofa keessatti	
3	Mooraa mana jireenyaa keessan keessatti	

4. Bobaa saree/adurree keessanii akkamitti qulqulleessitan fi gatan? (Filannoo sirrii irratti mallattoo "√" kaa'aa)

1	Qulqulleessuun lafa keessa awwaaluu	
2	Qulqulleessuun mana fincaanitti dabaluu	
3	Qulqulleessuun balfa manaa waliin gatuu	
4	Hin qulqulleessu	

5. Yeroo bobaa saree fi adurree qulqulleessitan meeshaalee ittisaa ni fayyadamtuu?

1. Eeyyee   2. Lakki

6. Tajaajila fayyaa beeyladaa kamiyyuu saree/adurree keessaniif ni argattu?

1. Eeyyee   2. Lakki

7. Gaaffii 6ffaaf deebiin kee "eeyyee" yoo ta'e, tajaajilli fayyaa beeyladaa armaan gadii keessaa isa kamtu saree/adurree keessaniif akka argamu irratti mallattoo "√" kaa'aa.

1	Talaallii	
2	Raammoo keessaa baasuu	
3	Akka hin dhalchine/hin dhalle gochuu ykn koolaasuu	
4	Tajaajila biroo	

8. Yeroo baay'ee isiin (maatiin keessan) saree/adurree keessan waliin wal ni qunnamtuu?

1. Eeyyee   2. Lakki

9. Foon hin bilchaanne/kuduraalee nyaattuu?   1. Eeyyee   2. Lakki

10. Nyaata dura harka dhiqattu?   1. Eeyyee   2. Lakki

Kutaa Sadii: Beekumsa abbootii qabeenyaa saree fi adurree raammoolee garaachaa saree fi adurree irratti fi dhukkuba bineensa irraa gara namaatti daddarbuu danda'u irratti

1. Raammooleen garaachaa maal akka ta'an ni beektuu?   A. Eeyyee   B. Lakki

2. Saroonni/adurreewwan raammoolee garaachaa qabaachuu akka danda'an beektu?

A. Eeyyee   B. Lakki

3. Raammoolee garaachaa adurree/saree beektu?   A. Eeyyee   B. Lakki

4. Gaaffii 3ffaaf deebiin kee "eeyyee" yoo ta'e, kanneen beektu keessaa muraasa tarreessi____

5. Mallattoolee raammoolee garaachaa adurree/saree beektuu? 1. Eeyyee   2. Lakki

6. Gaaffii 5ffaaf deebiin kee "eeyyee" yoo ta'e, kanneen beektu keessaa muraasa tarreessi

____

7. Raammoolee garaachaa adurree/saree bineensa gara bineensatti akkamiin akka darbu beektuu?   1. Eeyyee   2. Lakki

8. Gaaffii 7ffaaf deebiin kee "eeyyee" yoo ta'e, maloota dhibee kana dabarsaan keessaa muraasa tarreessaa____

9. Raammoolee garaachaa saree/adurree akkamitti akka to’atamu/ittifamu beektuu?

1. Eeyyee 2. Lakki

10. Gaaffii 9ffaaf deebiin kee "eeyyee" yoo ta'e, maloota raammoolee saree/adurree ofi irra ittisaan keessaa muraasa tarreessaa____

11. Raammoolee/ciccitaa raammoolee bobaa saree/adurree keessatti argitanii?

1. Eeyyee 2. Lakki

12. Raammoolee garaachaa Saree/adurree ta’anii saree/adurree irraa namatti daddarbuu danda’an beektu? 1. Eeyyee 2. Lakki

13. Gaaffii 12ffaaf deebiin kee "eeyyee" yoo ta'e, maqaa raammoolee kanaa muraasa tarreessaa____

14. Raammoolee garaachaa adurree/saree bineensa gara namaatti akkamiin akka darbu beektuu? 1. Eeyyee 2. Lakki

15. Gaaffii 14ffaaf deebiin kee "eeyyee" yoo ta'e, maloota dhibee kana dabarsaan keessaa muraasa tarreessaa____

Kutaa Afur: Ilaalcha abbootiin qabeenyaa saree fi adurree raammoolee garaachaa saree fi adurree irratti fi dhukkuba bineensa irraa gara namaatti daddarbuu danda’u irratti

1. Raammooleen garaachaa dhukkuba hamaa jettanii ni yaaddu? A. Eeyyee B. Lakki

2. Saree/adurree qabaachuun rakkoo fayyaa fida jettanii yaaddu? A. Eeyyee B. Lakki

3. Saree/adurree waliin taphachuun/xuxxuquun raammoolee garaachaaf nama saaxiluu danda’a jettanii ni yaaddu? A. Eeyyee B. Lakki

4. Nyaata dheedhii saree/adurree nyaachisuun dhukkuba raammoo garaachaa fiduu danda’a jettanii ni yaaddu? A. Eeyyee B. Lakki

5. Harka sirnaan dhiqachuun raammoolee garaachaa gara namaatti akka hin dabarre ni ittisa jettanii yaaddu? A. Eeyyee B. Lakki

6. Yeroo sareen/adurreen keessan dhukkuba raammoo garaachaa mudatu, qorichi/wal’aansi barbaachisaadha jettanii yaaddu? A. Eeyyee B. Lakki

7. Barnoonni fayyaa fudhaachuun raammoo garaachaa hir’isuu danda’a jettanii yaaddu? A. Eeyyee B. Lakki

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RESEARCH ARTICLE

Epidemiology of gastrointestinal parasites of dogs in four districts of central Ethiopia: Prevalence and risk factors

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Abstract

From February 2022 to April 2023, a cross-sectional study on dog gastrointestinal parasites was conducted in Bishoftu, Dukem, Addis Ababa, and Sheno, Central Ethiopia, with the aim of estimating the prevalence and evaluating risk factors. A total of 701 faecal samples were collected and processed using floatation and McMaster techniques. In dogs that were investigated, the overall prevalence of gastrointestinal parasites was 53.1% (372/701). Nematode (28.2%), cestode (8.4%), and protozoan (5.6%) parasite infections were detected in dogs in both single (42.2%) and combined (10.8%) infections. With respective prevalences of 16%, 9.8%, 5%, 3.9%, and 3.1% *Ancylostoma* spp., *Toxocara canis*, *Dipylidium caninum*, *Giardia* spp., and *Taenia/Echinococcus* spp. were the most common parasites. The prevalence of gastrointestinal parasites was significantly higher (P<0.05) in female dogs (73.8%, OR = 0.4), adult dogs (55.3%, OR = 0.4), dogs that were given raw food (57.9%, OR = 2.7), and dogs kept free outdoor (60.9%, OR = 2.4). The incidence of gastrointestinal parasites was also higher in dogs with diarrheal faecal consistency (89.1%, OR = 9.1) and dogs from highland areas (62.1%, OR = 1.8). In contrast, statistically significant variation in the prevalence of gastrointestinal parasites was not recorded among dogs of different breeds. The current study found that dogs in the studied locations had a high overall prevalence of gastrointestinal parasites. In conclusion, gastrointestinal parasites in dogs have the potential to pose a serious threat to public health, so addressing this issue requires a unified approach. Therefore, it is necessary to conduct detailed epidemiological and genetic research on dog parasites in vast study regions across various agro-ecologies zones and seasons in Ethiopia. Additionally, it is crucial to raise public awareness of the prevalence, effects on public health, and financial implications of dog gastrointestinal parasites in Ethiopia.

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1. Introduction

With a lengthy history of coexisting with humans, the dog was the first domesticated animal [1]. Dogs provide a variety of purposes for humans, including hunting, security, police assistance, military service, companionship, and, more recently, helping persons with disabilities

[2, 3]. Disease agents have spread as a result of this coexistence. These agents can infect one or more animal species, serving as important intermediate hosts for dog parasites [1].

Intestinal parasite infections are common in dogs [4]. The most prevalent organisms causing gastrointestinal disorders in dogs are parasites, mainly helminths and protozoa. These parasites cause diarrhoea, vomiting, anorexia, a dull coat, intestinal mucosal irritation, and bleeding. These can result in anaemia and possibly death [5]. *Toxocara canis*, *Ancylostoma caninum*, *Taenia hydatigena*, *Echinococcus* species, *Dipylidium caninum*, *Trichuris vulpis*, *Giardia* species, *Cryptosporidium* species, and *Cystoisospora* species are the most prevalent intestinal parasites in dogs [6].

Dogs living close to people are typically seen to be a major contributing element to the spread of zoonotic diseases, which can have detrimental effects. *Strongyloides stercoralis*, *Ancylostoma caninum*, *Dipylidium caninum*, *Toxocara canis*, *Echinococcus granulosus*, and *Trichuris vulpis* are the most prevalent zoonotic helminth parasites in dogs [7]. The oral-faecal cycle is how canine intestinal parasites spread. The release of eggs or larvae and oocysts or cysts into the environment is the main way that these parasites propagate. Direct contact with the definitive host, contaminated water and food, or indirect interaction with animal secretions and excreta can all spread zoonotic agents [6].

The prevalence of endoparasites in dogs varies from 5% to 70% in various regions [8–11]. According to these investigations, the most prevalent intestinal parasites in dogs are *Trichuris* species, *Toxocara* species, *Ancylostoma* species, and *Cystoisospora* species [12]. Therefore, ongoing research on the prevalence of various dog gastrointestinal parasites (GIT) and associated risk factors is essential for effective parasite control [13]. Dogs have a significant role in both urban and rural Ethiopian families, often acting as companion animals and house guardians [14]. There is a lack of reliable information on Ethiopia's dog and cat numbers [15]. Nonetheless, it is estimated that there are more than 5 million dogs in the nation [16]. The majority of Ethiopian dogs are stray animals that wander the streets, homesteads, slaughterhouses, butcher shops, and marketplaces. It has been discovered that these dogs have the largest parasite burdens [17, 18]. There are a lot of strays and unconfined dogs with a high prevalence of zoonotic parasites that pollute the environment, which is very concerning given the lack of public awareness about the welfare of these animals and the risks to public health from their diseases [18].

The prevalence of canine intestinal parasites in Ethiopia has been reported in a limited number of studies [19–21] with gastrointestinal helminth prevalence in dogs ranging from 52.9% to 94.6% [13, 22–24]. There are, however, few recent data on the incidence of canine gastrointestinal helminth parasites from central Ethiopia, specifically from Bishoftu, Dukem, Addis Ababa, and Sheno.

Information on gastrointestinal parasites that affect dogs in Ethiopia need therefore to be updated and expanded. It is essential to comprehend the epidemiology and all other facets of the disease in order to develop a practically relevant control program against diseases of high public health concern [25]. In order to establish baseline data for future initiatives aimed at reducing the risks to the human population, the study's goals were to estimate the prevalence of various gastrointestinal parasites in dogs and evaluate the associated risk factors in the Central Ethiopian districts of Bishoftu, Dukem, Addis Ababa, and Sheno.

2. Materials and methods

2.1. Study areas

The first research area, Bishoftu town (Ada'a district), is located 47 km southeast of Addis Ababa at an elevation of 1850 meters above sea level, with latitudes 9˚N and longitudes 40˚E.

The area has a bimodal rainfall pattern, with a longer wet season from June to September and a shorter rainy season from March to May. It receives 866 mm of rainfall annually, of which 84% falls during the long rainy season and the remainder during the short one. October through February is considered the dry season. The region experiences 61.3% relative humidity and average annual maximum and minimum temperatures of 26˚C and 14˚C, respectively [26]. According to species, there are 160,697 cattle, 22,181 sheep, 37,510 goats, 1660 horses, and 191,380 poultry [27], while the estimated number of dogs is 4188 [28].

Dukem, the second research location, is located adjacent to the main road to Adama, 37 km southeast of Addis Ababa. Between latitudes 8045'25" N and 8050'30" N and longitudes 38051'55" E and 38056'5" E, the study area physically covers 9,630.6 hectares. On average, it is about 2,100 meters above sea level. The average yearly high and low temperatures in the region are 27˚C and 22˚C, respectively and with an annual rainfall of *95 mm*. The towns of Bishoftu and Gelan, which are located in the southeast and the majority of the north, respectively [29]. It is believed that there are 944 dogs in Dukem [28].

Addis Ababa, the third research area, is located 2408 meters above sea level and at latitudes 90 3' N and 380 43' E. The average annual rainfall is 1201 mm, and the average lowest and highest temperatures are 9.4 and 23.2˚C, respectively. Rainfall has a bimodal trend, with the months of February through April seeing the smallest showers and June through September seeing the longest and heaviest rainfall [30]. Between 250,000 and 350,000 dogs are thought to live in Addis Ababa, with half of them being owned [31].

Sheno, the fourth research location, is situated in the North Showa Zone and is 78 kilometres from Addis Ababa, the country's capital. Sheno is situated between 1950 and 2918 meters above sea level at latitude 9˚20'N and longitude 39˚18'E. The terrain is flat and the agro-ecology is highlands. Bimodal rainfall patterns with unpredictable distribution are what define the region. Rainfall averages 1366.7 mm per year. The average yearly high and low temperatures in the region are 19.9˚C and 12.9˚C, respectively. Dogs are thought to number 4188, while the area's livestock population consists of 1.51 million cattle, 1 million sheep, 223,245 goats, donkeys, horses, and mules, with respective numbers of 254,553, 107,368 and 3,739 [32].

2.2. Study design

From February 2022 to April 2023, a cross-sectional study was carried out to determine the prevalence of gastrointestinal parasites in dogs and evaluate the associated risk factors (like origin, sex, age, breed, feeding condition, housing condition, agro-ecology and faecal consistency).

2.3. Sample size and sampling technique

The formula [33] for random sampling was used to get the necessary sample size. Based on an anticipated prevalence rate of 59.2% for dog gastrointestinal parasites, the sample size was determined [23]. Consequently, the following formula was used to determine the sample size:

$$n = \frac{1.96^2 \ \mathrm{Pexp}(1 - \mathrm{Pexp})}{d^2}$$

Where: n = desired sample size, Pexp = expected prevalence, and d = 0.05

According to the calculations, 371 dogs were anticipated to be part of the study; nevertheless, in order to improve the accuracy of the study's findings, 701 dogs (Bishoftu (305), Dukem (135), Addis Ababa (134) and Sheno (127)) were specifically taken into consideration for faecal and data collection in this study.

2.4. Sample collection

A verbal consent was informed to the dog owners and with their cooperation faecal samples were collected using disposable gloves. From each study animal 5–10 grams faecal sample was collected either straight from the rectum or from the top layer of recently voided faeces [24]. Then, the collected faecal samples were placed in labelled clean plastic containers (universal bottles) and preserved in 10% formalin then transported in icebox to the College of Veterinary Medicine and Agriculture of Adds Ababa University parasitology laboratory for further processing on the same day of collection. Sample left unprocessed on the same day were examined on the following days. A data recording format was used to document the study site, animal breed, sex, age, food and housing conditions, and the consistency of their faeces at the time of sampling. Physical examination of the faeces during sample collection was used to assess the consistency of the faeces. Dogs with the age < 6 months, 6 months up to 1 year and ≥ 1 year were considered as puppy, young and adult dogs, respectively [34].

2.5. Parasitological procedures

To find gastrointestinal parasite eggs or cysts, faecal samples were analyzed using the centrifuge-flotation technique in a saturated zinc sulphate solution (specific gravity = 1.20) [35]. Hence, around three grams of the faecal sample were weighed and put into mortar. Ten millilitres of flotation fluid (zinc sulphate solution) were then added, and the faecal sample inside the mortar was completely combined and crushed with a pestle. To get rid of the coarse debris, the solution was sieved into a beaker using a tea strainer. After adding the filtrate to the centrifuge tube and centrifuging it for three minutes at 3000 rpm, the floatation fluid was added until a cone-shaped top formed. A coverslip was then placed on top of the tube and let to stand for fifteen to twenty minutes. The coverslip was carefully lifted up and put on the microscopic slide [35, 36].

The entire slide was examined under a microscope, and parasite eggs, trophozoites, and cysts were discovered using a compound microscope with a 10x objective lens and a 40x objective magnification. To make it easier to identify protozoa and cysts, iodine solution was utilized. Morphologically, parasites were identified to the level of genera or species using ova/cyst identification keys, which were provided by [37, 38]. When at least one kind of parasite egg or cyst was found, the sample was deemed positive [39]. The McMaster technique was then used to re-analyse faecal samples that tested positive for helminth and protozoan ova using the flotation technique in order to assess the intensity/level of infection of each parasite in the study areas.

The number of eggs, cysts/oocysts per gram of faeces was calculated based on [40] as follows: three grams of faeces were mixed in a clean glass beaker with 42 ml of flotation solution (zinc sulphate solution) until the mixture is homogeneous, the mixture filtered with a sieve and the filtrate collected in a new beaker. The filtrate was taken with a pipette to fill both chambers of McMaster slide and let the slide stand for 5 minutes to allow parasite eggs/cysts to float to the surface. Then all eggs/cysts inside of the grid areas of both chambers were counted under microscope. Then, the total eggs/cysts per gram (EPG) of faeces was calculated. The total number of egg, cyst/oocysts of the two chambers was multipled by 50. This gives the EPG of faeces. Then based on [40], the EPG scores (intensity of infection) were categorized into three groups: mild, EPG $< 1{,}000$; moderate, $1{,}000 \leq$ EPG $< 10{,}000$; severe, EPG $\geq 10{,}000$.

2.6. Ethical consideration

The Addis Ababa University, College of Veterinary Medicine and Agriculture Research Ethics Committee (AAU-CVMA-REC) and the animal welfare guide for the care and use of animals (Ref. No.VM/ERC/36/02/15/2023) approved the animal handling ethics.

2.7. Data management and analysis

Microsoft Excel sheet 2010 was used to enter all of the generated data. IBM SPSS version 27, the Statistical Package for Social Sciences, was used to analyze the data. The relationship between helminths and protozoan parasitism and the risk factors (research site, sex, age, breed, feeding and housing conditions, faecal consistency, and agro-ecology) was examined using descriptive statistics and the chi-square ($\chi 2$) test. Binary logistic regression was used to compute the odds ratio (OR) and confidence interval for each risk factor, using the category with the lowest prevalence as a baseline for comparison. ANOVA was utilized to compare the means of three or more groups in order to analyze continuous data (faecal egg count or egg per gram of faeces (epg)). The statistical significance threshold was set at a P-value of less than 0.05.

3. Results

3.1. Overall prevalence of gastrointestinal parasites in dogs

Using coproscopic techniques, 701 dogs from Bishoftu, Dukem, Addis Ababa, and Sheno were examined for any gastrointestinal parasites. In all, 372 dogs (53.1%) tested positive for at least one kind of gastrointestinal parasite (Fig 1).

Bishoftu had a significantly ($P<0.001$) lower prevalence of gastrointestinal (GI) parasites than the other study locations. The prevalence of gastrointestinal parasites was significantly greater in female dogs ($P<0.001$) and adult dogs ($P = 0.006$). The frequency of GI parasites was significantly ($P<0.001$) greater in dogs kept free outdoors than in dogs maintained under better handling conditions. Compared to dogs that were fed cooked food, dogs that frequently consumed raw animal products were more likely to get parasite infections ($P<0.001$). For dogs that had previously been fed raw food, the odds ratio (OR) of gastrointestinal parasite presence was around three times greater. The prevalence of GI parasites was significantly ($P<0.001$) greater in dogs with diarrheal faecal consistency than in dogs with wet and dry faecal consistency. When comparing faecal samples with diarrheal consistency to samples with dry consistency, the OR of gastrointestinal parasite prevalence was around nine times greater for the former. The prevalence of GI parasites was significantly ($P<0.001$) greater in dogs from highland areas (Addis Ababa and Sheno) than in dogs from midland areas (Bishoftu and Dukem) (Table 1).

Single parasite infections had a significantly ($P<0.001$) greater prevalence of gastrointestinal parasites than mixed parasite infections (Table 2).

The incidence of nematodes was significantly ($P<0.001$) higher than that of protozoans and cestodes (Table 3).

3.2. Prevalence of gastrointestinal parasites by origin of dogs and parasite egg densities

In the study locations, *Strongyloides stercoralis*, *Physaloptera* spp., and *Diphyllobothrium* spp. were the least common gastrointestinal parasites, while *Ancylostoma* spp. was the most common. The incidence of particular gastrointestinal parasites in dogs from the four study sites varied statistically significantly ($P = 0.021$) (Table 4).

The parasite egg densities were calculated using the total mean egg per gram (EPG) of faeces, which came out to be 1176.8 (Table 5).

3.3. Prevalence of specific gastrointestinal parasites by sex and age of dogs

Ancylostoma spp. and *Toxocara canis* eggs were the most prevalent gastrointestinal parasites in male and female dogs, respectively. Similarly, adult and young dogs were frequently found to have eggs of *Ancylostoma* spp., while puppies were primarily affected by *Toxocara canis* (Table 6).

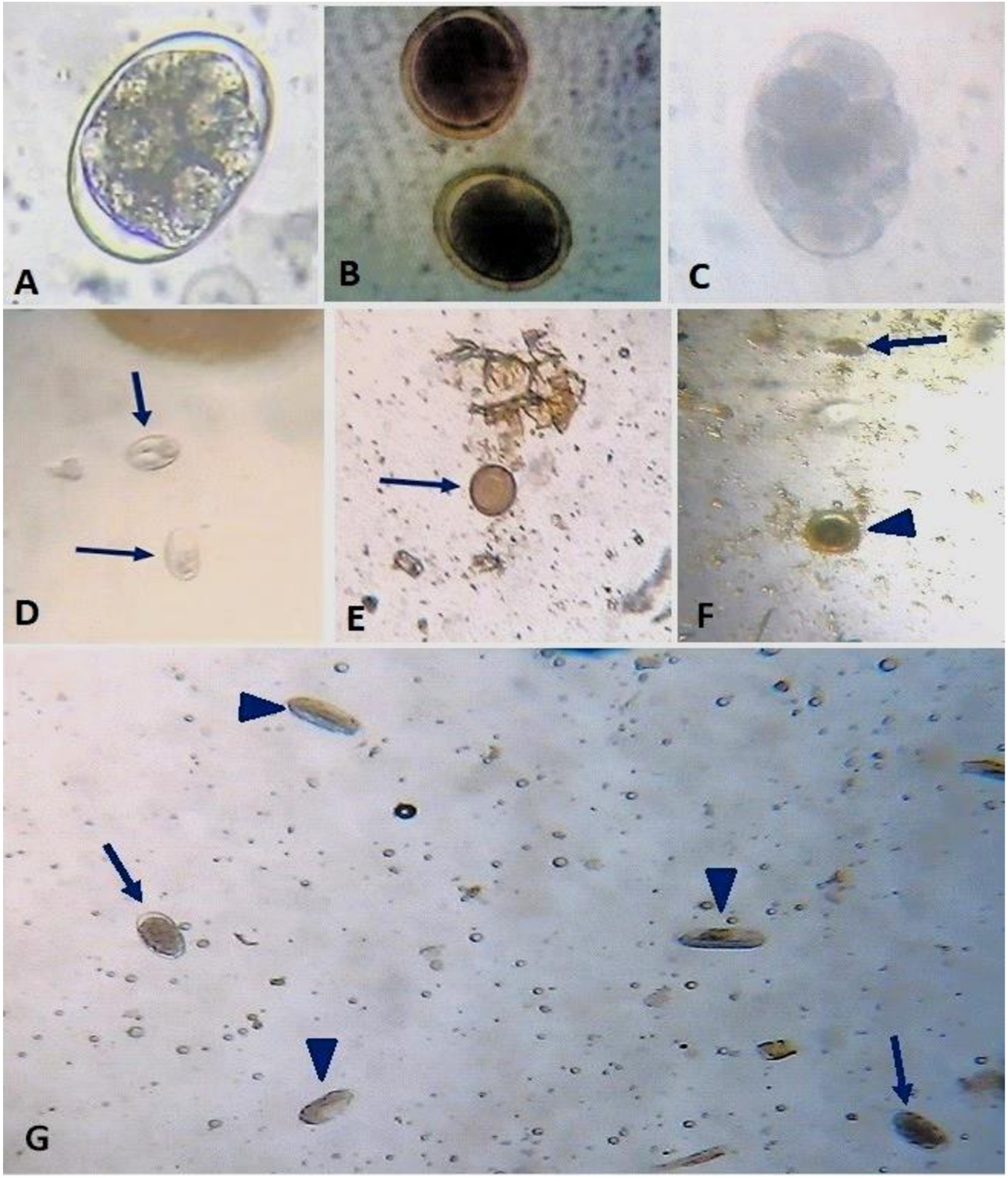

Fig 1. *Ancylostoma* spp. from 2 yrs. female dog X40 (A), *Toxocara canis* of 1.5 yrs. male dog X40 (B) from Bishoftu, *Dipylidium caninum* of 4 yrs. old male dog X40 from Addis Ababa (C). *Giardia* spp. from 4 yrs. male dog X10 (A) from Dukem (D). *Taenia* spp. from 3 yrs. male dog X10 from Sheno (E). Mixed infection of *Ancylostoma* spp. (arrow) and *Toxocara canis* (arrowhead) from 4 yrs. male dog X10 from Dukem (F). Mixed infection of *Ancylostoma* spp. (arrow) and *Physaloptera* spp. (arrowhead) from 2yrs. female dog X10 from Bishoftu (G).

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Table 1. Frequency, prevalence, 95% confidence interval and Odds ratio of gastrointestinal parasites identified in dogs relative to risk factors.

Risk factors	Category level	Frequency (%)	Number of Positive (%)	95% CI	AOR	95% CI Per Adjusted Odds Ratio		χ2 (P-value)
						Lower	Upper	
Origin	Bishoftu	305 (43.5)	123 (41.6)	35–46	Ref	Ref	-	35.384 (<0.001)
	Dukem	135 (19.3)	87 (64.4)	56–73	2.682	1.762	4.082	
	Addis Ababa	134 (19.1)	83 (61.9)	54–70	2.408	1.587	3.654	
	Sheno	127 (18.1)	79 (62.2)	54–71	2.435	1.591	3.727	
Sex	Male	617 (88)	310 (50.2)	46–54	Ref	Ref		16.487 (<0.001)
	Female	84 (12)	62 (73.8)	64–83	0.358	0.215	0.597	
Age	Puppy	36 (5.1)	14 (38.9)	22–56	Ref			10.109 (0.006)
	Young	48 (6.8)	17 (35.4)	21–49	0.515	0.259	1.025	
	Adult	617 (88)	341 (55.3)	51–59	0.444	0.241	0.819	
Breed	Cross	29 (4.1)	13 (44.8)	26–64	Ref	Ref		5.120 (0.077)
	Local	603 (86)	314 (52.1)	48–56	0.748	0.354	1.582	
	Exotic	69 (9.8)	45 (65.2)	54–77	1.726	1.025	2.904	
Feeding condition	Cooked	141 (20.1)	48 (34.0)	26–42	Ref	Ref		25.649 (<0.001)
	Uncooked	560 (79.9)	324 (57.9)	54–62	2.660	1.807	3.915	
Housing condition	Free in home/compound	175	68 (38.9)	25–41	Ref	Ref	-	40.999 (<0.001)
	Kennel/leashed	76	30 (39.5)	28–51	0.750	0.420	1.340	
	Free outdoor	450	274 (60.9)	56–65	2.387	1.452	3.925	
Agro-ecology	Midland	440 (62.8)	210 (47.7)	43–52	Ref	Ref		13.529 (<0.001)
	Highland	261 (37.2)	162 (62.1)	56–68	1.792	1.312	2.449	
Faecal consistency	Dry	56 (8)	18 (32.1)	20–45	Ref	Ref		79.195 (<0.001)
	Diarrheic	119 (17)	106 (89.1)	83–95	9.140	5.012	16.669	
	Wet	526 (75)	248 (47.2)	43–51	0.531	0.295	0.954	
Total		701 (100)	372 (53.1)	49–57	-	-	-	696.997 (<0.001)

95% CI, 95% confidence interval; AOR, Adjusted odds ratio, χ2, chi-square.

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3.4. Prevalence of group of gastrointestinal parasites by feeding and housing conditions of dogs

The current investigation showed that dogs with uncooked food feeding experience had greater prevalences of protozoa and cestodes, while dogs with prepared food feeding experience had higher prevalences of mixed parasite infection in the study locations (Table 7).

Dogs kept free outdoor had higher rates of nematode, cestode, and protozoan infections based on housing conditions (Table 8).

Table 2. Gastrointestinal parasite diversity of dogs examined from the four study sites.

Infection with	Origin				Total Frequency (%)	Prevalence (%)	P-value
	Bishoftu (n = 305)	Dukem (n = 135)	Addis Ababa (n = 134)	Sheno (n = 127)			
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite	182 (58.4)	48 (35.6)	51 (38.1)	49 (38.6)	328 (46.9)	46.9	<0.001
One parasite	99 (32.5)	71 (52.6)	67 (50)	58 (45.7)	296 (42.2)	53.1	
Two parasites	15 (4.9)	10 (7.4)	11 (8.2)	14 (11)	50 (7.1)		
Three parasites	9 (3)	6 (4.4)	5 (3.7)	6 (4.7)	26 (3.7)		

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Table 3. Group of gastrointestinal parasites detected from the faeces of examined dogs.

Type of parasite	Origin				Prevalence (%)	Total Prevalence (%)	P-value
	Bishoftu (n = 305)	Dukem (n = 135)	Addis Ababa (n = 134)	Sheno (n = 127)			
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite (n = 328)	182 (55.5)	48 (14.6)	50 (15.2)	48 (14.6)	46.9	46.9	<0.001*
Nematode (n = 198)	69 (34.8)	44 (22.2)	45 (22.7)	40 (20.2)	28.2	53.1	
Cestode (n = 59)	20 (33.9)	16 (27.1)	12 (20.3)	11 (18.6)	8.4		
Protozoa (n = 39)	11 (28.2)	11 (28.2)	9 (23)	8 (20.5)	5.6		
Mixed infection (n = 77)	23 (30)	16 (20.8)	18 (23.4)	20 (25.9)	11		
Total (n = 701)	305 (100)	135(100)	134(100)	127(100)	100	100	

https://doi.org/10.1371/journal.pone.0316539.t003

4. Discussion

A total of 701 faecal samples were randomly selected for this cross-sectional investigation on dog gastrointestinal parasites, and they were processed using the flotation and McMaster procedures. The binary logistic regression test was used to examine the odds of the prevalence and

Table 4. Frequencies and percentages of specific gastrointestinal parasites of dog.

Parasite	Bishoftu (n = 305)		Dukem (n = 135)		Addis Ababa (n = 134)		Sheno (n = 127)		Total Frequency (%)	P-value
	N (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI		
Single Parasite Infection										
Nematode										
***Ancylostoma* spp.**	39 (12.8)	9–17	26 (19.3)	13–26	23 (17.2)	11–24	24 (18.9)	12–26	112 (16)	<0.001
Toxocara canis	21 (6.9)	4–10	16 (11.9)	6–18	20 (14.9)	9–21	12 (9.5)	4–15	69 (9.8)	<0.001
Strongyloides stercoralis	6 (1.9)	0–4	1 (0.7)	1–2	1 (0.8)	1–2	1 (0.8)	1–2	9 (1.3)	0.003
***Physaloptera* spp.**	4 (1.3)	0–3	2 (1.5)	1–4	1 (0.8)	1–2	2 (1.6)	1–4	9 (1.3)	0.014
Cestode										
Dipylidium caninum	12 (3.9)	2–6	9 (6.7)	2–11	7 (5.2)	1–9	7 (5.5)	1–10	35 (5)	<0.001
***Taenia/Echinococcus* spp.**	7 (2.3)	1–4	5 (3.7)	0–7	5 (3.8)	0–7	5 (3.9)	1–7	22 (3.1)	0.001
***Diphyllobothrium* spp.**	3 (0.9)	0–2	2 (1.5)	1–4	2 (1.5)	1–4	2 (1.6)	1–4	9 (1.3)	0.034
Protozoa										
***Giardia* spp.**	7 (2.3)	1–4	8 (5.9)	1–9	7 (5.2)	1–8	5 (3.9)	1–7	27 (3.9)	0.001
***Isospora* spp.**	4 (1.3)	0–3	3 (2.2)	0–5	2 (1.5)	1–4	3 (2.4)	0–5	12 (1.7)	0.014
Multiple Parasite Infection										
Ancylostoma* spp. *and Toxocara canis	5 (1.6)	0–3	5 (3.8)	0–7	4 (2.9)	0–6	4 (3.2)	0–6	18 (2.6)	0.006
***Ancylostoma* spp. *and Physaloptera* spp.**	3 (0.9)	0–2	1 (0.7)	1–2	1 (0.8)	1–2	1 (0.8)	1–2	6 (0.9)	0.034
***Toxocara canis and Physaloptera* spp.**	3 (0.9)	0–2	1 (0.7)	1–2	1 (0.8)	1–2	4 (3.2)	0–6	9 (1.3)	0.034
***Ancylostoma* spp. *and Taenia* spp.**	3 (0.9)	0–2	2 (1.5)	1–4	3 (2.2)	0–5	3 (2.4)	0–5	11 (1.6)	0.034
***Toxocara* spp. *and Strongyloides* spp.**	1 (0.3)	0–1	1 (0.7)	1–2	2 (1.5)	1–4	2 (1.6)	1–4	6 (0.9)	0.223
***Ancylostoma* spp., *Toxocara* spp. *and Physaloptera* spp.**	4 (1.3)	0–3	4 (2.9)	0–6	3(2.2)	0–5	3 (2.4)	0–5	14 (2)	0.014
***Ancylostoma* spp., *Toxocara* spp. *and Taenia* spp.**	2 (0.7)	0–2	1 (0.7)	1–2	2 (1.5)	1–4	1 (0.8)	1–2	6 (0.9)	0.084
***Toxocara* spp. *Physaloptera* spp. *and Giardia* spp.**	3 (0.9)	0–2	1 (0.7)	1–2	-	-	2 (1.6)	1–4	6 (0.9)	0.034
Total	127 (41.6)	35–46	87 (64.4)	56–73	83 (61.9)	54–70	79 (62.2)	54–71	372 (53.1)	0.021

95% CI, 95% confidence interval; *N*, number.

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Table 5. Mean egg per gram of faeces (EPG) of specific gastrointestinal parasites of dog.

Parasite	Number (%) of Dogs infected	EPG		
		Mean	SD	P-value
Single Parasite Infection				
Nematode				
***Ancylostoma* spp.**	112 (16)	979**	1205	
Toxocara canis	69 (9.8)	1479.1***	1477	
Strongyloides stercoralis	9 (1.3)	761.1**	918.8	
***Physaloptera* spp.**	9 (1.3)	1444.4***	1863.8	
Total (nematode)	198 (28.2)	1461.1***	1339.7	<0.001
Cestode				
Dipylidium caninum	35 (5)	1265.7***	1367.4	
***Taenia/Echinococcus* spp.**	17 (2.4)	1175***	1246	
***Diphyllobothrium* spp.**	9 (1.3)	966.7**	903.3	
Total (cestode)	59 (8.7)	2100***	2404.1	<0.001
Protozoa				
***Giardia* spp.**	27 (3.9)	964.8**	1175.9	
***Isospora* spp.**	12 (1.7)	1195.8***	1365	
Total (protozoa)	39 (5.6)	4100***	-	<0.001
Multiple Parasite Infection				
Ancylostoma* spp. and *Toxocara canis	18 (2.6)	1233.3***	1369	
***Ancylostoma* spp. and *Physaloptera* spp.**	6 (0.9)	408.3**	156.3	
***Toxocara canis* and *Physaloptera* spp.**	9 (1.3)	1583.3***	1586	
***Ancylostoma* spp. *and Taenia/Echinococcus* spp.**	11 (1.6)	654.6**	843.7	
***Toxocara* spp. and *Strongyloides* spp.**	6 (0.9)	941.7**	770	
***Ancylostoma* spp., *Toxocara* spp. and *Physaloptera* spp.**	14 (2)	860.7**	1227	
***Ancylostoma* spp., *Toxocara* spp. and *Taenia/Echinococcus* spp.**	6 (0.9)	1925***	2048	
***Toxocara* spp. *Physaloptera* spp. and *Giardia* spp.**	6 (0.9)	2166.7***	1440	
Total (mixed infection)	77 (11)	1770***	1974.7	<0.001
Total	372 (53.1)	1176.8***	1533	0.008

SD, Standard deviation

**, mild, EPG <1,000

***, moderate, $1{,}000 \leq$ EPG $< 10{,}000$.

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confidence interval of each risk factor, and the relationship between the risk factors and protozoan parasites and helminths was examined. The mean differences of the faecal egg count or egg per gram of faeces were also compared using ANOVA. The study's findings showed that gastrointestinal parasites are common in dogs in the locations under investigation. The overall prevalence of gastrointestinal parasites found in this study was greater than the 19.6%, 33.3%, and 39% prevalences found in earlier studies by [41–43].

However, the overall rate found in this study is generally lower than what has been found by [22–24, 44–47]. These differences in the prevalence of gastrointestinal parasites in dogs may be due to changes in climatic circumstances, animal management, sampling procedures, demographic factors, anthelmintic use, and diagnostic methods used [48, 49].

Compared to mixed infections, single parasite species infections seem to be far more prevalent. This is consistent with previous findings of [24] in Ethiopia's Hawassa town. Numerous other earlier research have reported similar findings [23, 45]. Conversely, research conducted in different regions of Ethiopia by [21, 50] have shown that the proportion of mixed species

Table 6. Prevalence of specific gastrointestinal parasites of dogs relative to their sex and age.

Parasite	Sex		P-value	Age			P-value
	Male (n = 617)	Female (n = 84)		Puppy (n = 36)	Young (n = 48)	Adult (n = 617)	
	N (%)	*N (%)*		*N (%)*	*N (%)*	*N (%)*	
Nematode							
***Ancylostoma* spp.**	98 (15.9)	14 (16.7)	0.783	0 (0.0)	7 (14.6)	105 (17)	0.024
Toxocara canis	46 (7.5)	23 (27.4)	<0.001	6 (16.7)	4 (8.3)	59 (9.6)	0.356
Strongyloides stercoralis	7 (1.1)	2 (2.4)	0.341	0 (0.0)	0 (0.0)	9 (1.5)	0.538
***Physaloptera* spp.**	9 (1.5)	0 (0.0)	0.265	0 (0.0)	0 (0.0)	9 (1.5)	0.538
Cestode							
Dipylidium caninum	33 (5.3)	2 (2.4)	0.241	2 (5.6)	1 (2.1)	32 (5.2)	0.628
***Taenia/Echinococcus* spp.**	14 (2.2)	8 (9.5)	<0.001	4 (11.1)	0 (0.0)	18 (2.9)	0.010
***Diphyllobothrium* spp.**	5 (0.8)	4 (4.8)	0.003	0 (0.0)	0 (0.0)	9 (1.5)	0.538
Protozoa							
***Giardia* spp.**	24 (3.9)	3 (3.6)	0.887	2 (5.6)	0 (0.0)	25 (4.1)	0.321
***Isospora* spp.**	12 (1.9)	0 (0.0)	0.197	0 (0.0)	0 (0.0)	12 (1.9)	0.436
Total	248 (40.2)	56 (66.7)	<0.001	14 (38.9)	12 (25)	278 (45.1)	0.006

N, number.

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infections is significantly higher than that of monoinfection by a single parasite. As previously mentioned, these differences in the parasite population's makeup could be caused by environmental contamination levels as well as feeding and management practices. The likelihood of finding eggs during faecal analysis may also be decreased by the fact that parasites like some cestode and *Strongyloides* species often pass gravid segments or L1 larvae in faeces instead of eggs [51].

The current study showed that adult dogs had a higher prevalence of gastrointestinal parasites than puppies and young dogs is consistent with data from [13, 22–24, 44, 45, 47, 51]. Adult dogs may have greater opportunities to interact with other dogs and contaminated settings, which is likely the cause [51]. Other earlier findings, however, have demonstrated that infection rates were higher in younger dogs than in adults [46, 50]. This could point to variations in the way the animals are cared for, where consistent use of anthelmintic drugs may lessen positive in mature dogs. However, puppies are susceptible to infection by some common nematode species through congenital and transmammary mechanisms, and the risk of infection may increase until treatment is initiated [46].

This study's finding that female dogs had a far greater prevalence of gastrointestinal parasites than male dogs is consistent with earlier researches by [4, 10, 22, 52]. Contacts with several male dogs during estrus and the stress of pregnancy and lactation may contribute to the greater prevalence of infection in females by adversely influencing their immune systems [53].

Table 7. Prevalence of group of gastrointestinal parasites of dog relative to their feeding condition.

Feeding condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Cooked (n = 141)	91 (64.5)	23 (16.3)	6 (4.3)	3 (2.1)	18 (12.8)	<0.001
Uncooked (n = 560)	237 (42.3)	175 (31.3)	53 (9.5)	36 (6.4)	59 (10.5)	

N, number.

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Table 8. Prevalence of group of gastrointestinal parasites of dog relative to their housing condition.

Housing condition	Group of parasites					P-value
	No parasite	Nematode	Cestode	Protozoa	Mixed infection	
	N (%)	*N (%)*	*N (%)*	*N (%)*	*N (%)*	
Kennel/leashed (n = 76)	46 (60.5)	18 (23.7)	6 (7.9)	0 (0.0)	6 (7.9)	$<$0.001
Free in home/compound (n = 175)	105 (60)	35 (20)	9 (5.1)	10 (5.7)	16 (9.1)	
Free outdoor (n = 450)	177 (39.3)	145 (32.2)	44 (9.8)	29 (6.4)	55 (12.2)	
Total	328 (46.8)	198 (28.2)	59 (8.4)	39 (5.6)	77 (11)	

N, number.

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In addition, female dogs are more likely to come into contact with contaminated environments while they are looking for food, mostly to feed their pups [56]. Another explanation is that tissue-encysted *Ancylostoma* and *Toxocara* worms may get reactivated if the females are pregnant, and some of them may develop in the intestines before releasing eggs in the form of faeces. Contrary to this widespread belief, it has been observed that male dogs have a higher frequency of gastrointestinal parasites than female dogs [13, 23, 24, 42, 44, 51].

Dogs with diarrheal faecal consistency had a significantly greater prevalence of gastrointestinal parasites, which may indicate that the animals were affected with gastrointestinal parasitism-related clinical disease. This is consistent with earlier researches shown by [43, 54]. Diarrhoea is one of the primary clinical signs of gastrointestinal parasitism [53], and it may be caused by the helminth parasite's inflammation and destruction of the absorptive epithelium of the gastrointestinal tract [54].

In the current study, giving dogs raw food was significantly linked to a higher prevalence of gastrointestinal parasites than giving them cooked food on a regular basis. This supports the earlier studies by [4, 43, 55, 56], which found that dogs given raw animal items and leftovers from homes and restaurants had a significantly higher risk of contracting gastrointestinal parasites than dogs fed properly prepared or packaged feed. Dogs fed raw feed had the highest prevalence of gastrointestinal helminths (93.7%), followed by dogs that occasionally fed prepared (37.5%) and raw animal products (90.7%) [20]. The fact that cooking can destroy or inactivate infectious eggs or cysts of gastrointestinal parasites that can be spread among dogs through feed explains why dogs that were fed raw had the highest incidence of these parasites [4].

Despite the fact that every dog examined in this study was owned, over 64% of them fell into the category of stray or outside canines. Compared to dogs housed in a home/compound, dogs that have unrestricted access to the outdoors are much more likely to get gastrointestinal parasite infections. This supports the findings of [10, 47, 51]. Free-roaming pets have a preference for hunting and consume mice, rats, insects, mollusks, poultry, migratory birds, frogs, and small mammals [57]. These foods increase the likelihood that dogs will come into contact with infectious parasite stages on the ground or in intermediate/paratenic hosts. This suggests that food items that are discarded into the environment will be more likely to include soilborne parasites, such as the carnivorous hookworms and the ascarids, which are the most common. Dogs that roam around and scavenge seem to be more likely to come into contact with a contaminated environment [47]. Conversely, the highest incidence (86.3%) was found in dogs that shared a shelter with family [44].

Toxocara canis and *Ancylostoma* spp. were frequently found parasites in dogs, which is consistent with study reports from Ethiopia and other countries [22, 24, 41, 45, 47, 58]. These results are readily explained by inadequate hygienic circumstances, the use of anthelmintics, and a lack of health management measures [59].

The dominance of these parasites is expected due to their very high fecundity that allows easy contamination of the environment. In this regard, this study has also demonstrated that *Toxocara* was the most prolific nematode parasite followed by *Physaloptera* and *Ancylostoma* species. The ability of the parasites to pass from generation to generation through transplacental and transmammary routes [60] might have also contributed to the high prevalence. Female *Toxocara* species produces an average of 12500 eggs per day, the range being 9500–55000). Specifically, presence of the free-living dogs and daily discharge of *Toxocara* eggs in the environment (about 200,000 eggs/day) can create a favourable ground for persistence of infection [61].

From cestode parasites, *Dipylidium caninum* eggs were the most prevalent compared to *Taenia* and *Echinococcus* species indicating that infections obtained from the environment were more common than those contracted by eating raw animal items such offals. This agrees with the reports of [41] in Mexico and [24] in Hawassa town while other researchers have reported either lower prevalence [43] or higher prevalences [22, 23, 46, 47, 58]. Such variation could be associated with variation in the diagnostic techniques used, the study population and the agroecological factors affecting the distribution of flea intermediate hosts. For example, *Dipylidium* egg clusters are frequently observed adhered to the perineal region [62], hence sample collection methods may impact the degree of infection detection. *Dipylidium* is a flea-born parasite. Flea larvae are infected by consuming eggs originating from either gravid segments passed in faeces or eggs from degenerated segments within the intestine. Animals get infected through accidental ingestion of infected fleas infesting their body [63]. The limited amount of infected offals consumed may be the reason for the comparatively low prevalence of cestode parasites in this study when compared to the dominant nematodes. Another explanation for the low prevalence would be that the intact gravid segment's genital pore is closed, which stops free shedding of eggs inside the digestive tract [55].

Despite its extremely low prevalence, *Giardia* was one of the most common protozoan parasites found in dogs. Relatively lower prevalence in Egypt [4] and higher prevalences in Wondo Genet town of Ethiopia [22], Nigeria [46] and Morocco [44] were recorded. Although the zoonotic potential of canine giardiasis remains largely an unresolved issue [2], dogs and cats can carry strains of *Giardia* which are potentially infective to humans, and therefore, the zoonotic potential must be considered, especially for immunocompromised people [64].

Concerning the average egg count of the specific gastrointestinal parasites, the mean egg count was the highest in case of *Toxocara canis* followed by *Physaloptera* spp. and *Dipylidium caninum* with moderate parasitic load. The current finding was higher than the mean count reported by [65]. Whereas [66] reported that *Ancylostoma* spp. and *Uncinaria* spp. had the highest and least egg per gram of faeces (EPG), respectively. This variation could be attributed to the differences in health care and degree of environmental contamination with infective stage, frequent mixing of pets with stray dogs which might have the infections, lack of awareness of dog parasites and their control strategies [65]. Specifically, presence of the free-living dogs and daily discharge of *Toxocara* eggs in the environment (about 200,000 eggs/day) can be considered as a reason of this fact why ascaridoid nematodes are prevalent [61]. The degree of environmental contamination with nematodes and cestodes is also crucial for human health. Considering the information obtained from dog owners, it may be concluded that a high number of EPG is due to occasional and accidental dogs deworming [67].

The current study's limitation is that, because of budgetary and resource limitations, molecular tests were not used to corroborate these findings; instead, this method was left for future study on the identification of gastrointestinal parasites in dogs.

5. Conclusion and recommendations

The total prevalence of gastrointestinal parasites in dogs was found to be high in this study (53.1%). The majority of monoparasite species (28.2%) are nematode parasites. There was a statistically significant higher prevalence of gastrointestinal parasites in female dogs, adults, dogs that were given raw food, dogs kept free outdoor, and dogs from highland areas. Faecal consistency has statistically significant association with the prevalence of gastrointestinal parasites in the examined dogs. *Ancylostoma* spp. was the most common parasite (16%) detected followed by *Dipylidium caninum* (5%) and *Giardia* spp. (3.9%), suggesting that gastrointestinal parasite infections are still common enough to affect dogs in the studied locations, resulting in these animals' morbidity and mortality. The infection was moderately severe. One health approach is necessary to address this public health hazard because parasitic diseases in dogs can have a substantial negative economic impact in addition to being a serious public health concern.

Given all of this evidence, more thorough research is required to completely comprehend the zoonotic and economic effects of many gastrointestinal parasites in dogs. To identify the parasites to species level in wider study areas in various agro-ecologies and seasons, comprehensive epidemiological and genetic investigations should be carried out. Additionally, it is strongly advised that the general public should be made aware of the prevalence, effects on public health, and financial implications of dog gastrointestinal parasites.

Supporting information

S1 Data. Data-dog GIT parasites-PONE-D-24-49776R1_FTC.
(XLSX)

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Original Article

Gastrointestinal parasites of owned cats in three districts of Central Ethiopia: Prevalence and risk factors

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ABSTRACT

This present, cross-sectional study investigated gastrointestinal parasites in owned cats was carried out across Bishoftu, Dukem, and Addis Ababa city and towns in Central Ethiopia from February 2022 to April 2023. The primary objectives were to estimate the prevalence and assess the risk factors associated with these parasites. A total of 213 faecal samples were collected and processed using flotation and McMaster techniques. An overall prevalence of 34.7% (74/213) of gastrointestinal parasites was recorded in the examined cats. The cats harboured nematode (14.6%), cestode (12.7%), and protozoan (5.6%) parasites in single (32.9%) and mixed (1.9%) species. Specifically, *Toxocara cati*, *Dipylidium caninum*, *Taenia* spp., *Giardia* spp., and *Physaloptera* spp. were the more frequently identified parasites, with prevalences of 9.4%, 8.9%, 3.8%, 2.8%, and 2.8%, respectively. Statistically significant differences ($P < 0.05$) were observed in the prevalence of gastrointestinal parasites among cats of different sexes, ages, and feeding conditions. Thus, higher prevalence rates were observed in females (49.1%, OR = 2.3), young cats (70%, OR = 4.7), and those consuming uncooked food (40.5%, OR = 3.6). Faecal consistency also showed a statistically significant association ($P < 0.05$) with the presence of gastrointestinal parasites. However, no significant differences were noted in the prevalence among cats of different housing conditions, seasons, or agro-ecological zones. Cats sharing shelter with families had the highest prevalence of gastrointestinal parasites (52.2%). In conclusion, this study uncovered a notably high occurrence of gastrointestinal parasites in cats in the surveyed regions, emphasizing the imperative of adopting a One Health strategy to address the zoonotic parasites found in cats, which pose significant public health risks.

1. Introduction

Domestic cats (*Felis catus*) are the sole feline species known for their exclusive close contact with humans (Adhikari et al., 2023) and are commonly embraced as companion animals (Cossío et al., 2021). However, there remains a scarcity of evidence-based research to substantiate whether these pets receive adequate care or if their health issues are occasionally disregarded (Howell et al., 2016). Cats play an important role in society as integral members of the family environment. However, this proximity can potentially pose health risks to humans, as cats serve as hosts to various zoonotic parasites. These parasites not only directly impact the health of the feline companions (Silva et al., 2023c) but also have implications for human health.

Cats harbour a variety of gastrointestinal parasites, posing an increasing concern from veterinary and public health standpoints due to their effects on the health of cats and their ability to transmit infections to humans (Abbas et al., 2022). While numerous studies have explored gastrointestinal parasites in cats across the USA (Lee et al., 2014; Hoggard et al., 2019; Loftin et al., 2019), Europe (Symeonidou et al., 2018; Overgaauw and Nijsse, 2020; Silva et al., 2020; Genchi et al., 2021), and Asian countries (Rubel et al., 2003; Lee et al., 2019; Souza et al., 2023; Silva et al., 2023c, b), relatively little is known about these parasites and their zoonotic implications in Africa (Abbas et al., 2022).

Gastrointestinal parasites are widespread, and infections depend on various risk factors including geographical region, frequency of antiparasitic treatment, lifestyle, season of the year, and the cat population composition. Several epidemiological studies have demonstrated that stray cats present a high frequency of parasites (Sauda et al., 2019; Genchi et al., 2021). While some of these agents infect cats via the faecal-oral route as the main transmission mechanism, others can infect animals via intact skin penetration by larvae as well as via intermediate or paratenic hosts, and through the mother's uterus or milk (Arruda

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et al., 2021).

The manifestation of clinical symptoms in cats depends on the helminth species, their abundance, the presence of concurrent multiple infections, and the age and individual immunological status of the cat. Domestic cats are hosts to a wide variety of intestinal parasites. Recent reports from many countries around the world have shown that cats are commonly infected by different helminths and protozoa species (Barua et al., 2020; Morandi et al., 2020; Silva et al., 2020). The parasitism can vary from asymptomatic cases to severe intestinal clinical manifestations, especially in puppies, kittens, and immunocompromised individuals (Soe et al., 2023). Cats with subclinical infections sometimes show the symptoms of dull coat, vomiting, diarrhea, and weight loss, eventually leading to death in chronic infections. In addition, parasitized cats have become more susceptible to other bacterial and viral infections (Soe et al., 2023). Cats are the main source of several parasitic diseases, including toxoplasmosis, giardiosis, visceral larval migrans syndrome, and ocular larval migrans syndrome, which affect humans and other animals (Krecek et al., 2010).

Cats are susceptible to several gastrointestinal parasites (Silva et al., 2023c) some of these parasites can cause serious diseases in humans when exposed through direct cat/human interactions or indirectly via contact with contaminated soil, food, water or fomites (Fusaro et al., 2022; Nourollahi Fard et al., 2024). A wide variety of parasitic helminths are implicated to affect cats, of which several species are known to possess zoonotic importance (Darabi et al., 2021). Nematodes such as *Toxocara cati*, *Toxascaris leonina*, *Ancylostoma* sp., cestodes such as *Diphylobothrium* sp., *Dipylidium caninum*, and protozoan oocysts such as *Isospora felis*, *Isospora rivolta*, and *Eimeria* spp. are common in companion and stray cats (Rabbani et al., 2020). Young cats and dogs are often infected by feline roundworms, specifically by *Toxocara cati* and *Toxocara canis*. Infection with *Toxocara cati* or *Toxocara canis*, termed toxocariosis, is known to inflict joint stiffness, intestinal disorders, emaciation, and growth retardation in affected cats (Lee et al., 2014).

Due to public and animal health concerns, conducting studies on parasites affecting cats and dogs remains a continuous task, with the most relevant aim of establishing appropriate control measures (Oliveira-Sequeira et al., 2002). However, in Ethiopia, very limited attention has been given to the gastrointestinal parasites of cats. Therefore, the objectives of the present study were to estimate the prevalence of different species of gastrointestinal parasites in cats and to assess the related risk factors in Bishoftu and Dukem towns and Addis Ababa city in Central Ethiopia.

2. Materials and methods

2.1. Study areas

The first study area, Bishoftu town (Ada'a district) (Fig. 1), is located at a latitude of 9°N and longitude of 40°E, approximately 47 km southeast of Addis Ababa, at an elevation of 1850 m above sea level. The area experiences a bimodal rainfall pattern with a short rainy season from March to May and a longer wet season from June to September. It receives an annual rainfall of 866 mm, with 84% occurring in the long rainy season and the remaining in the short rainy season. The dry season extends from October to February. The area's average annual maximum and minimum temperatures are 26 °C and 14 °C, respectively, with a relative humidity of 61.3% (ADARDO, 2007). The population of livestock includes 160,697 cattle, 22,181 sheep, 37,510 goats, 1660 equines, and 191,380 poultry (CACC, 2003). No statistical information is recorded on the cat populations in the three study areas.

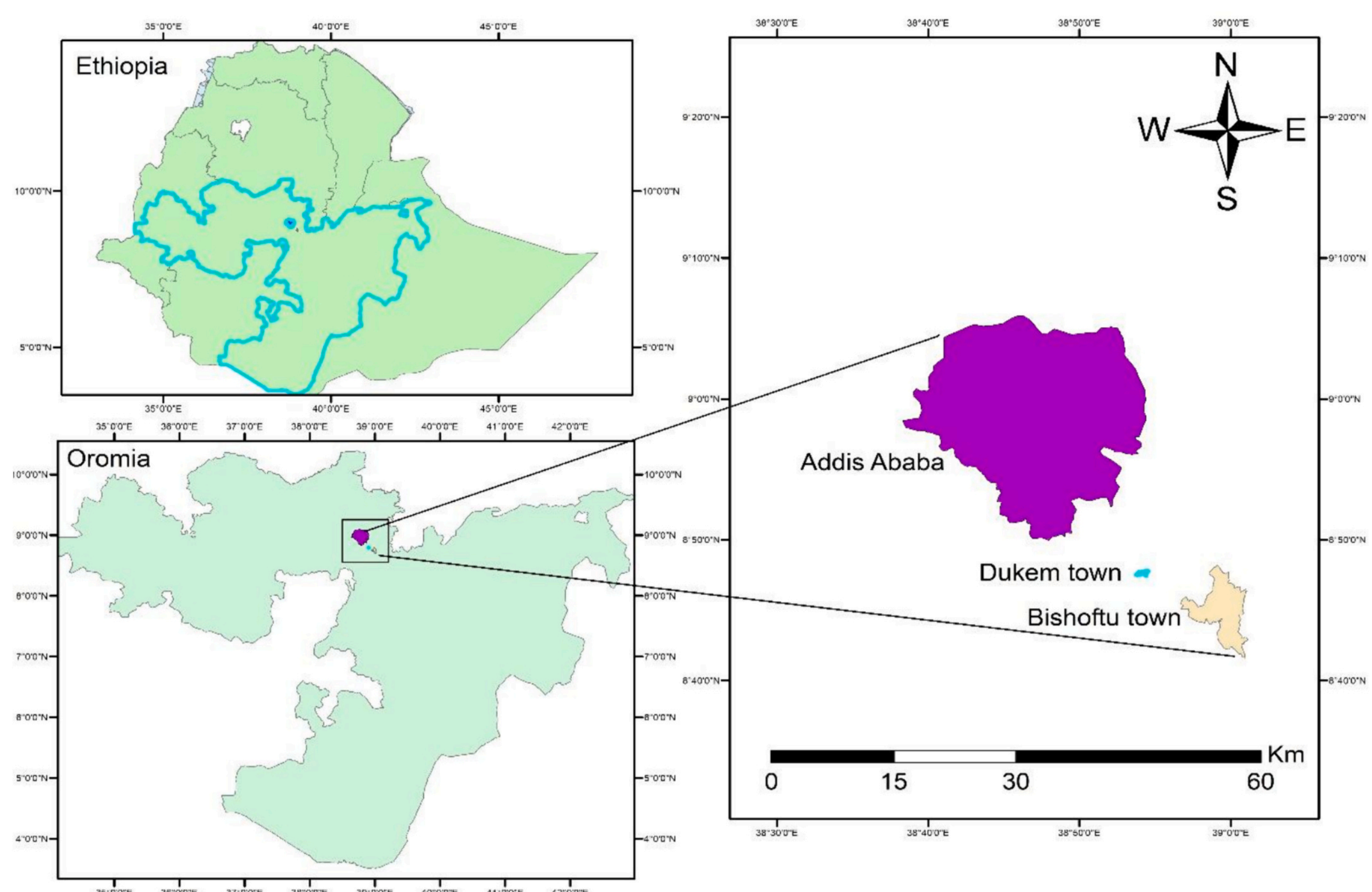

Fig. 1. Map of Ethiopia showing location of the present study areas.

The second study area, Dukem (Fig. 1), is situated 37 km southeast of Addis Ababa, adjacent to the main road to Adama. Geographically, the area spans 9630.6 ha between latitudes 8°45′25" N and 8°50'30" N, and longitudes 38°51′55" E and 38°56'5" E. It has an average altitude of 2100 m above sea level. The town is bordered by the towns of Bishoftu and Gelan to the southeast and most of the north, respectively. Four nearby Peasant Associations (PAs) of the Akaki District border the remaining eastern and western portions of the town (OUPI, 2017).

The third study area, Addis Ababa (Fig. 1), is located at a latitude of 9°3′ N and longitude of 38°43′ E, at an altitude of 2408 m above sea level. The average annual minimum and maximum temperatures are 9.4 °C and 23.2 °C, respectively, and the mean annual rainfall is 1201 mm. The pattern of rainfall is bimodal, with long and heavy rainfall received during the months of June to September, while short and small showers are received during February to April (Tegegne et al., 2000).

2.2. Study design

A cross-sectional type of study design was employed to identify and estimate the prevalence of gastrointestinal parasites and to assess the risk factors of owned cats in Bishoftu, Dukem, and Addis Ababa towns/city (Fig. 1) in central Ethiopia from February 2022 to April 2023.

2.3. Sampling and sample collection

During the study period, a total of 213 faecal samples were purposively collected from owned cats of the study areas. Faecal samples were collected with the permission and assistance of the cat owners. Approximately 5–10 g of faecal samples from each study animal were collected either directly from the rectum of the animals or from recently voided faeces using a disposable glove (Pereira et al., 2017). The collected samples were then placed in labelled clean plastic containers (universal bottles) and preserved in 10% formalin, then transported in an icebox to the College of Veterinary Medicine and Agriculture of Addis Ababa University parasitology laboratory for further processing on the same day of collection. Any sample left unprocessed on the first day was stored in the refrigerator at 4 °C to be processed in the following days. At the time of sampling, the date, study site, breed, sex, age, feeding condition, housing condition, and faecal consistency were recorded on a data recording format. The faecal consistency was determined by physical observation of the faeces during sample collection. Cats aged from 6 months up to 1-year-old were considered as young, whereas those older than 1-year were considered as adults.

2.4. Parasitological procedures

Faecal samples were examined using a flotation technique in a saturated zinc sulphate ($ZnSO_4$; specific gravity = 1.20) solution to identify the eggs, cysts, and oocysts of gastrointestinal parasites (Taylor et al., 2016). Three grams of the faecal sample was measured and added to a mortar, then 42 ml of flotation fluid was added to the faecal sample contained in the mortar. It was crushed well with a pestle and mixed thoroughly. The solution was sieved using a tea strainer into a beaker to remove rough materials. Then the filtrate was added to a centrifuge tube and centrifuged at 3000 rpm for 3 min. A top-up of flotation fluid was added until a cone shape was formed at the top of the centrifuge tube. Next, a coverslip was placed on the top of the tube and allowed to stand for 15–20 min. The coverslip was raised gently and placed on a microscopic slide. An iodine solution was used to facilitate protozoan and cyst identification, and slides were examined under a microscope. The sample was considered positive when at least one type of parasite egg, cysts/oocysts, was detected (MAFF, 1986).

The eggs, cysts/oocysts were identified by observing the slides under 10× and 40× magnification of a compound microscope, using ova/oocyst identification keys to the level of genera or species based on the key provided by Hendrix (2003) and Zajac and Conboy (2012). Faecal samples positive for ova of helminths and protozoa using flotation technique were re-analysed using a standard McMaster technique.

The number of eggs/cysts per gram of faeces was calculated based on Taylor et al. (2016) as follows: three grams of faeces were mixed in a clean glass beaker with 42 ml of zinc sulphate flotation solution until the mixture was homogeneous. The mixture was then filtered with a sieve, and the filtrate was collected in a new beaker. Next, the filtrate was taken with a pipette to fill both chambers of a McMaster slide, and the slide was allowed to stand for 5 min to allow parasite eggs/cysts to float to the surface. Then all eggs/cysts inside the grid areas of both chambers were counted under a microscope. Subsequently, the total eggs/cysts per gram (epg) of faeces were calculated. The total number of eggs/cysts of the two chambers was multiplied by 50. This gives the epg of faeces.

2.5. Data management and analysis

All generated data were entered into a Microsoft Excel sheet (2010). The data were analysed using Statistical Package for Social Sciences (IBM SPSS version 27) statistical software. Descriptive statistics and chi-square ($\chi 2$) test were used to analyse the association of the risk factors (study site, sex, age, feeding condition, housing condition, faecal consistency, season, and agro-ecology) with helminths and protozoan parasitism. Odds ratios (OR) and confidence intervals of each risk factor were calculated using the category with the lowest prevalence as a baseline for comparison using binary logistic regression. For analysis of continuous data (faecal egg count or eggs per gram of faeces (epg)), ANOVA was used to compare means of three or more groups. A *P*-value <0.05 was considered statistically significant.

3. Results

3.1. Overall prevalence of gastrointestinal parasites in cats

A total of 213 owned cats (Bishoftu (103), Dukem (55), and Addis Ababa (55)) were sampled for coprological analysis. Out of the total of 213 faecal samples examined, 74 (34.7%) cats were positive for at least one type of gastrointestinal parasite. Of the cats sampled for the presence of parasites, 160 (75.1%) were males and 53 (24.9%) were females, with a prevalence of gastrointestinal parasites at 48 (30%) and 26 (49.1%), respectively. Similarly, 10 (4.7%) young and 203 (95.3%) adult cats were examined for the presence of gastrointestinal parasites, with a prevalence of 7 (70%) and 67 (33%), respectively. Statistically significant differences ($P < 0.05$) in the prevalence of gastrointestinal parasites were observed among cats of different sexes, ages, feeding conditions, and faecal consistencies (Table 1). The prevalence of gastrointestinal parasites with one (single species) and two types (mixed species) of parasites was 32.9% and 1.9%, respectively, with a statistically significant difference ($P < 0.05$) in prevalence of gastrointestinal parasites (Table 2).

Findings of the present study showed that nematodes had the highest prevalence of 14.6%, followed by cestodes and protozoans with respective prevalences of 12.7% and 5.6% (Table 3).

3.2. Prevalence of gastrointestinal parasites by origin of cats

Overall, 35 (33.9%) cats from Bishoftu, 22 (40%) from Dukem, and 17 (30.9%) from Addis Ababa were positive for gastrointestinal parasites. The study indicated that *Toxocara cati* from Bishoftu (9.7%, 95% CI = 4–16), Dukem (10.91%, 95% CI = 2–19), and Addis Ababa (7.27%, 95% CI = 0–14) was the most prevalent gastrointestinal parasite. Conversely, *Isospora* spp. from Bishoftu (0.97%, 95% CI = 0–3) was the least prevalent gastrointestinal parasite. No statistically significant difference ($P > 0.05$) was observed in the prevalence of gastrointestinal parasites among cats of the three study sites (Table 4). The determination of densities of parasite eggs, recorded as the total mean eggs per gram (epg) of faeces, was 902.6 (Table 5).

Table 1
Prevalence of gastrointestinal parasites in cats based on various risk factors of animal traits.

Risk factors	Category Level	Frequency (%)	Number of Positive (%)	95% CI	AOR	95% CI Per Adjusted Odds Ratio		χ2 (*P*-value)
						Lower	Upper	
Origin	Addis Ababa	55 (25.8)	17 (30.9)	18–44	Ref	Ref	–	
	Bishoftu	103 (48.4)	35 (33.9)	25–43	1.295	0.659	2.547	1.053 (0.591)
	Dukem	55 (25.8)	22 (40)	27–53	0.869	0.431	1.754	
Sex	Male	160 (75.1)	48 (30)	23–37	Ref	Ref	–	6.377 (0.012*)
	Female	53 (24.9)	26 (49.1)	35–63	2.247	1.190	4.244	
Age	Young	10 (4.7)	7 (70)	35–100	4.736	1.187	18.898	5.753 (0.016*)
	Adult	203 (95.3)	67 (33)	26–40	Ref	Ref	–	
Feeding condition	Cooked	50 (23.5)	8 (16)	5–27	Ref	Ref	–	10.123 (0.001*)
	Uncooked	163 (76.5)	66 (40.5)	33–48	3.572	1.576	8.096	
Housing condition	Kennel	4 (1.9)	0 (0)	–	Ref	Ref	–	6.777 (0.079)
	Open air in the compound	48 (22.5)	6 (12.5)	6–40	4846.1	–	–	
	Free roaming in & outside the compound/home	160 (75.1)	56 (35)	28–42	8987.7	–	–	
	Share with family	23 (10.8)	12 (52.2)	30–74	17,623	–	–	
Agro-ecology	Highland	55 (25.8)	17 (30.9)	18–44	Ref	Ref	–	0.480 (0.488)
	Midland	158 (74.2)	57 (36.1)	29–44	1.262	0.654	2.435	
Faecal consistency	Dry	21 (9.9)	6 (28.6)	8–50	Ref	Ref	–	21.271
	Diarrheic	25 (11.7)	19 (76)	58–94	7.917	2.118	29.595	(<0.000*)
	Wet	167 (78.4)	49 (29.3)	22–36	1.038	0.381	2.832	

* : Represent statistically significant difference ($p \leq 0.05$); 95% CI: 95% confidence interval; AOR: Adjusted odds ratio, χ2: chi-square; %: percentage.

Table 2
Proportion of mono and mixed parasite species recorded in cats of three study sites.

Results	Infection with	Origin			Total Percentage	Total Prevalence (%)	P-value
		Bishoftu ($n = 103$)	Dukem ($n = 55$)	Addis Ababa ($n = 55$)			
		Frequency (%)	Frequency (%)	Frequency (%)			
Negative	No parasite	68 (66)	33 (60)	38 (69.1)	65.3	65.3	
Positive	One parasite	34 (33)	20 (36.4)	16 (29.1)	32.9	34.7	<0.000*
	Two parasites	1 (0.9)	2 (3.6)	1 (1.8)	1.9		
Total		103 (100)	55 (100)	55 (100)	100	100	

* Represent statistically significant difference ($p \leq 0.05$); %: percentage.

Table 3
Group of gastrointestinal parasites detected in the faeces of examined cats.

Group of parasites	Origin			Prevalence (%)	Total Prevalence (%)	P-value
	Bishoftu (n = 103)	Dukem (n = 55)	Addis Ababa ($n = 55$)			
	Frequency (%)	Frequency (%)	Frequency (%)			
No parasite ($n = 139$)	68 (48.9)	33 (23.7)	38 (27.3)	65.3	65.3	
Nematode ($n = 31$)	17 (54.8)	8 (25.8)	6 (19.4)	14.6	34.7	
Cestode ($n = 27$)	13 (48.2)	8 (29.6)	6 (22.2)	12.7		0.869
Protozoa ($n = 12$)	4 (33.3)	4 (33.3)	4 (33.3)	5.6		
Mixed infection ($n = 4$)	1 (25)	2 (50)	1 (25)	1.9		
Total	103 (100)	55 (100)	55 (100)	100	100	

%: percentage.

3.3. *Prevalence of gastrointestinal parasites by sex and age*

In male cats, *Toxocara (T.) cati* and *Dipylidium (D.) caninum* eggs, each with a prevalence of 9.6% from Bishoftu, *T. cati* with 14.6% from Dukem, and *D. caninum* with 8.3% from Addis Ababa, were the most prevalent gastrointestinal parasites. In female cats, *Taenia* spp. eggs with 15% from Bishoftu, *D. caninum* and *Giardia* trophozoites each with a prevalence of 14.3% in cats from Dukem, and *T. cati*, *Taenia* spp., *Giardia* spp., and *Giardia* trophozoites each with a prevalence of 10.5% from Addis Ababa were the most prevalent gastrointestinal parasites (Figs. 2 and 3). Statistically significantly ($P < 0.05$) higher prevalence of gastrointestinal parasites in female cats than male cats was observed in the study areas. The odds ratio of gastrointestinal parasite presence was about 2 times higher in female cats (OR = 2.247; 95% CI = 35–63) when compared to male cats (30%, 95% CI = 23–37) (Tables 1 and 6). Similarly, statistically significantly ($P < 0.05$) higher prevalence of gastrointestinal parasites in young cats than adult cats was recorded in the study areas. The OR of gastrointestinal parasite presence was about 5 times higher in young cats (OR = 4.736; 95% CI = 35–100) as compared to the adult cats (33%, 95% CI = 26–40) (Tables 1 and 6).

3.4. *Prevalence of gastrointestinal parasites by feeding and housing conditions*

Findings from the study demonstrated the presence of statistically significantly higher prevalence of gastrointestinal parasites ($P < 0.05$) in cats owned with the experience of feeding uncooked food compared to those owned by individuals feeding cooked food. The odds ratio of gastrointestinal parasite presence was about 4 times higher in those cats owned by individuals feeding uncooked food (OR = 3.572; 95% CI =

Table 4
Gastrointestinal parasite species detected in the faeces of cats of the three study sites.

Parasites	Bishoftu (n = 103)		Dukem (n = 55)		Addis Ababa (n = 55)		Total Frequency (%)	P-value
	N (%)	95% CI	*N* (%)	95% CI	*N* (%)	95% CI		
Single Parasite Infection								
Nematode								
Ancylostoma spp.	2 (1.9)	0–6	1 (1.8)	0–5	1 (1.8)	0–5	4 (1.9)	0.870
Toxocara cati	10 (9.7)	4–16	6 (10.9)	2–19	4 (7.3)	0–14	20 (9.4)	0.798
Strongyloides stercoralis	1 (0.9)	0–3	0 (0)	–	0 (0)	–	1 (0.5)	0.585
Physaloptera spp.	4(3.88)	0–8	1 (1.8)	0–5	1 (1.8)	0–5	6 (2.8)	0.661
Cestode								
Dipylidium caninum	10 (3.8)	5–17	5 (9.1)	2–19	4 (7.3)	1–17	19 (8.9)	0.940
Taenia spp.	3 (2.9)	0–6	3 (5.5)	0–14	2 (3.6)	0–12	8 (3.8)	0.445
Protozoa								
Giardia spp.	2 (1.9)	0–10	2 (3.6)	0–12	2 (3.6)	0–12	6 (2.8)	0.993
Giardia trophozoites	1 (0.9)	0–3	2 (3.6)	0–9	2 (3.6)	0–9	5 (2.3)	0.439
Isospora spp.	1 (0.9)	0–3	0 (0.0)	–	0 (0)	–	1 (0.5)	0.585
Multiple Parasite Infection								
Ancylostoma spp. and *Taenia* spp.	0 (0)	–	1 (1.8)	0–3	0 (0)	–	1 (0.5)	0.236
Toxocara spp. and *Strongyloides* spp.	1 (0.9)	0–3	1 (1.8)	0–3	1 (1.8)	0–5	3 (1.4)	0.872
Total	35 (33.9)	25–43	22 (40)	27–53	17 (30.9)	18–44	74 (34.7)	0.591

95% CI: 95% confidence interval; *N*: number; %: percentage.

Table 5
Mean egg per gram of faeces (epg) of different gastrointestinal parasites of cats in the study areas.

Parasites	epg						Total mean	F-test	P-value
	Bishoftu (n = 103)		Dukem (n = 55)		Addis Ababa (n = 55)				
	Mean	Standard deviation	*Mean*	Standard deviation	*Mean*	Standard deviation			
Single Parasite Infection									
Nematode									
Ancylostoma spp	133.33	133.33	1500.00	–	1500.00	–	680	9.954	<0.001*
Toxocara cati	1025.00	1025.00	958.33	958.33	287.50	287.50	857.50	15.659	<0.001*
Strongyloides stercoralis	150.00	–	–	–	–	–	150	6.607	<0.001*
Physaloptera spp.	2775.00	2775.00	3000.00	–	100.00	–	2366.67	5.092	<0.001*
Cestode									
Dipylidium caninum	1159.09	1159.09	1300.00	1300.00	960.00	960.00	1152.27	12.401	<0.001*
Taenia spp.	1133.33	1133.33	1600.00	1600.00	300.00	300.00	1070	3.718	<0.001*
Protozoa									
Giardia spp.	833.33	833.33	1150.00	1150.00	150.00	150.00	741.67	6.920	6.920
Giardia trophozoites	3000.00	–	3000.00	–	1650.00	1650.00	2460	6.408	<0.001*
Isospora spp.	50.00	–	–	–	–	–	250	3.926	<0.001*
Multiple Parasite Infection									
Ancylostoma spp. and *Taenia* spp.	–	–	100.00	–	–	–	100	1.162	0.319
Toxocara spp. and *Strongyloides* spp.	100.00	–	100.00	–	100.00	–	100	3.983	<0.001*
Total	410.19	1028.786	554.55	1163.339	212.73	691.028	902.55	–	0.989

* Represent statistically significant difference ($p \leq 0.05$).

33–48) compared to those cats owned with the experience of feeding cooked food (16%, 95% CI = 5–27) (Tables 1 and 7).

3.5. Prevalence of gastrointestinal parasites by faecal consistency and agro-ecology

Observations from the current study indicate statistically significantly ($P < 0.05$) higher prevalence of gastrointestinal parasites in cats with diarrheic faecal consistency compared to those cats with dry and wet faecal consistency. The odds ratio of prevalence of gastrointestinal parasites was about 8 times higher for samples with diarrheic consistency (OR = 7.917; 95% CI = 58–94) compared to samples with dry consistency (28.6%; 95% CI = 8–50). However, no statistically significant difference ($P > 0.05$) was observed in the prevalence of gastrointestinal parasites among cats from various agro-ecological zones of the study areas (Table 1).

4. Discussion

The results of this study demonstrated a high prevalence (34.7%) of gastrointestinal parasites in cats within the study areas. Despite strong evidence suggesting the presence of zoonotic gastrointestinal parasites in the cats examined, there is little information on the occurrence of gastrointestinal parasites among cats in Ethiopia. The overall prevalence of gastrointestinal parasites recorded in this study is higher than the previous findings reported by Jittapalapong et al. (2007), Palmer et al. (2010), and Lorenzini et al. (2007), who noted prevalences of 11.9%, 18.4%, and 20.5%, respectively. However, it is lower than the prevalences reported by Nateneal et al. (2015), Hussam (2015), Pereira et al. (2017), Mohmad et al. (2020), Lima et al. (2021) and Abbas et al. (2022), which were 80.7%, 47.8%, 49.5%, 39.3%, 40% and 52.4%, respectively. These discrepancies in the prevalence of gastrointestinal parasites may be attributed to variations in environmental conditions, seasons conducive to parasite biology, geographical locations, animal management practices, veterinary facilities, public awareness of cat

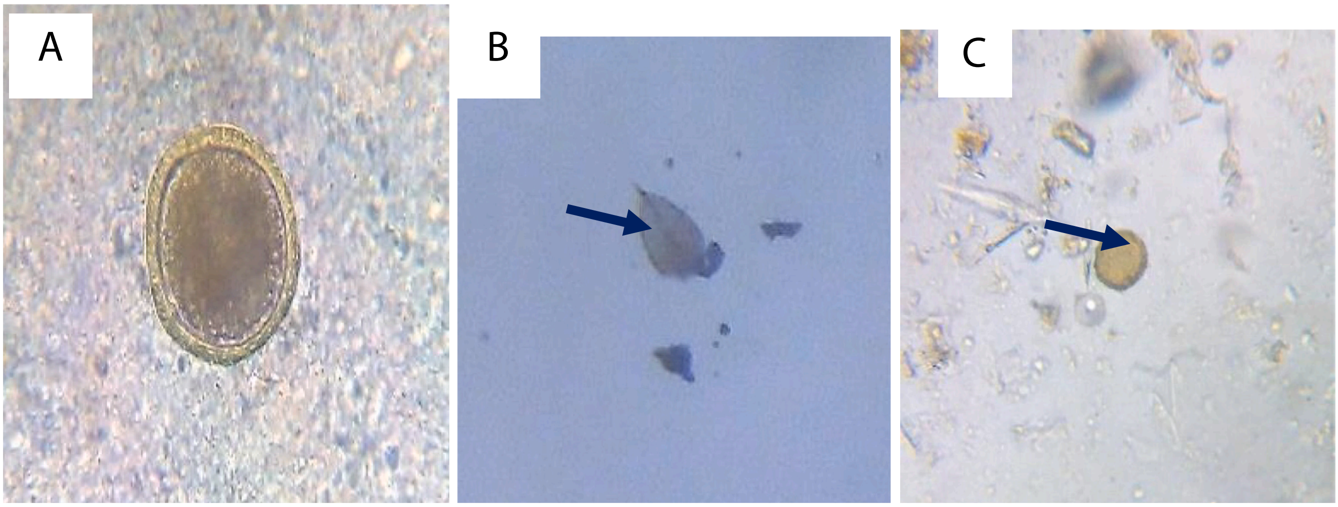

Fig. 2. *Toxocara cati* of 2 yrs. female cat x40 (A). *Giardia trophozoite* from 3 yrs. female cat x10 (B) from Bishoftu town. *Taenia* spp. from 2 yrs. male cat x10 (C) from Addis Ababa.

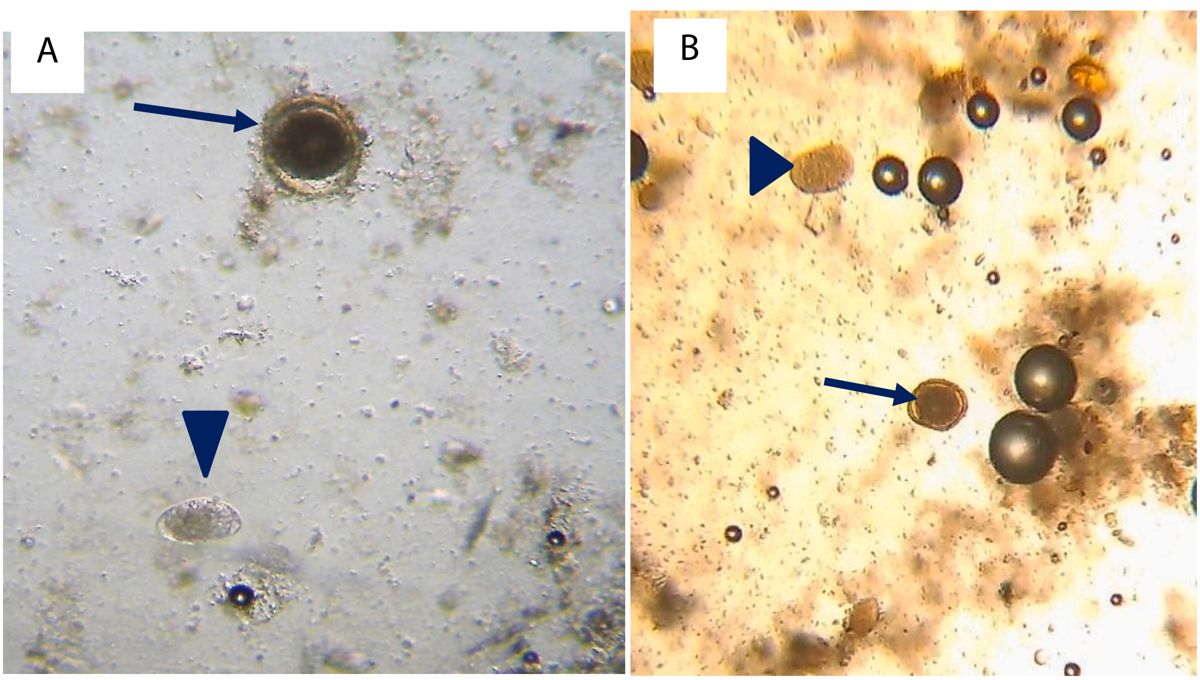

Fig. 3. Mixed infection of *Anchylostoma* spp. (arrow head) and *Toxocara* spp. (arrow) from 7 months male cat x10 (A). *Toxocara* spp. (arrow) and *Strongyloides* spp. (arrow head) from1 yr. male cat x10 (B) from Bishoftu town.

care, sampling protocols, age composition of the sample, demographic factors, anthelmintic usage, and diagnostic techniques, as previously suggested (Mundim et al., 2007; Katagiri and Oliveira-Sequeira, 2007; Alimohammad et al., 2011).

The observation of a higher frequency of monoparasitism (32.9%) compared to polyparasitism (1.9%) in cats of the present study is in accordance with earlier findings by Nateneal et al. (2015), who reported a 68.8% prevalence for single species and 9.6% for mixed-species of parasites in cats. Similarly, Nourollahi Fard et al. (2024) reported higher prevalence (54%) of single gastrointestinal parasites in free-roaming cats of Iran. This predominance is likely due to the limited contact domestic cats have with infected intermediate hosts and their environments as previously suggested (Silva et al., 2023b). However, this observation contrasts with that of Mohmad et al. (2020), who indicated that cats frequently harboured more than one helminth species, with prevalences of 6.98% for single helminth infections and 19.50% for dual helminth infections. This finding also disagrees with other studies such as those by Lorenzini et al. (2007), Katagiri and Oliveira-Sequeira (2007), and Ramirez-Barrios et al. (2004).

The findings of higher prevalence of gastrointestinal parasites in cats younger than 1-year of age (70%) compared to those older than 1 year (33%) of age in the present study is consistent with findings by Oliveira-Sequeira et al. (2002), Rubel et al. (2003), Lorenzini et al. (2007), and Hoggard et al. (2019). Higher prevalence of gastrointestinal parasites in younger cats is likely due to their lack of prior exposure to parasites and their immature immune systems, which increases their susceptibility to infections. Maternal milk is also considered a major route of infection (Lorenzini et al., 2007). Conversely, this observation does not align with findings from Nateneal et al. (2015) in Harar town, where the prevalences were 73.7% for young cats and 78.6% for adult cats, nor with

Table 6
Summary of the prevalence of gastrointestinal parasites in cats relative to their sex and age.

Parasite	Sex		P-value	Age		P-value
	Male (*n* = 160)	Female (*n* = 53)		Young (n = 10)	Adult (*n* = 203)	
	N (%)	*N (%)*		*N (%)*	*N (%)*	
Nematode						
Ancylostoma spp.	4 (2.5)	0 (0)	0.245	1 (10)	3 (1.5)	0.053
Toxocara cati	16 (10)	4 (7.5)	0.596	1 (10)	19 (9.4)	0.946
Strongyloides stercoralis	1 (0.6)	0 (0)	0.564	0 (0)	1 (0.5)	0.824
Physaloptera spp.	6 (3.8)	0 (0)	0.153	0 (0)	6 (3)	0.581
Cestode						
Dipylidium caninum	14 (8.8)	5 (9.4)	0.880	0 (0)	19 (9.4)	0.311
Taenia spp.	0 (0)	8 (15.1)	<0.001*	1 (10)	7 (3.4)	0.287
Protozoa						
Giardia spp.	2 (1.2)	4 (7.5)	0.016*	0 (0)	6 (3)	0.581
Giardia trophozoites	0 (0)	5 (9.4)	<0.001*	0 (0)	5 (2.5)	0.616
Isospora spp.	1 (0.6)	0 (0)	0.564	0 (0)	1 (0.5)	0.824
Total	44 (27.5)	26 (49.1)	0.012*	3 (30)	67 (33)	0.016*

* Statistically significant difference ($p < 0.05$); *N*: number; %: percentage.

Table 7
Summary of the prevalence of gastrointestinal parasites of cats relative to their feeding condition.

Parasite	Feeding condition		P-value
	Cooked (*n* = 50)	Uncooked (*n* = 163)	
	N (%)	*N (%)*	
Nematode			
Ancylostoma spp.	1 (2)	3 (1.8)	0.942
Toxocara cati	0 (0)	20 (12.3)	0.009*
Strongyloides stercoralis	0 (0)	1 (0.6)	0.579
Physaloptera spp.	1 (2)	5 (3.1)	0.690
Cestode			
Dipylidium caninum	1 (2)	18 (11)	0.050
Taenia spp.	0 (0)	8 (4.9)	0.110
Protozoa			
Giardia spp.	0 (0)	6 (3.7)	0.169
Giardia trophozoites			
Isospora spp.	1 (2)	0 (0)	0.070
Total	4 (8)	61 (37.4)	0.001*

* Statistically significant difference ($p < 0.05$); *N*: number; %: percentage.

those of Jittapalapong et al. (2007) in Bangkok, Thailand, Adhikari et al. (2023) in Nepal and Ridwan et al. (2023) in Indonesia all of which reported higher prevalence in young than adult cats.

The significantly higher prevalence ($P < 0.5$) of gastrointestinal parasites in female cats (49%) compared to male cats (30%) (Table 1) is supported by a previous study by Arruda et al. (2021) that reported higher prevalences in female cats (25.8%) compared to male cats (22.9%), Bourgoin et al. (2022), showed higher prevalence (15.3%) in female cats than the male (13.8%) and Silva et al. (2023b) recoded higher prevalence (64.5%) in female than the male (35.5%) which is probably attributed to the fact that females hunt more, mainly to feed their youth. Likewise, higher prevalence of gastrointestinal parasites in female than in male cats was reported by Nateneal et al. (2015) from Harar town. On the contrary, higher prevalence of gastrointestinal parasites in male (12.1%) than in female (11.7%) cats was reported by Jittapalapong et al. (2007) and Pereira et al. (2017) reported higher prevalences of gastrointestinal parasites in male cats (51.4%, respectively) than in female cats (48.2%).

The significantly higher prevalence ($P < 0.5$) of gastrointestinal parasites in cats fed uncooked food (40.5%) compared to those fed cooked food (16%) (Tables 1 and 7) in the present study agrees with the previous findings by Bhowmik et al. (2020), who indicated that diet is a critical factor influencing the transmission of helminth parasites. This study found that 92 (63%) of the cats that were fed canned food as their staple diet were free from gastrointestinal parasites, unlike the higher prevalence found in cats typically fed homemade food such as boiled rice, milk, fish, and chicken. Raw fish and chicken can increase the risk of parasitic infections, and homemade foods sometimes lead to nutritional deficiencies, particularly in essential amino acids, calcium, phosphorus, and vitamin D. Likewise, Bourgoin et al. (2022) also reported higher prevalence of GIT parasites in cats with a statistically significant ($P < 0.05$) difference based on food type, including raw meat feeding.

The statistically significantly ($P < 0.05$) higher prevalence of gastrointestinal parasites in cats with diarrheic faecal consistency (76%) aligns with previous studies by Mukutmoni et al. (2022), who reported a 10% prevalence, and by Arruda et al. (2021), who reported a 20.3% prevalence in cats with diarrheic faeces. This is most probably attributed to the fact diarrhea is considered a major clinical sign of parasitic infections in cats, as in other domestic animals (Arruda et al., 2021).

The observation that the majority of the study cats had a higher prevalence of a single parasite species (32.9%), while only 1.9% had a mixed parasite infection (Table 2), agrees with a previous study by Mukutmoni et al. (2022) in which monoparasite species were predominantly detected in majority of the faecal samples, while the co-occurrence of *Dipylidium* spp. and hookworm (1.9%) was encountered at a lower prevalence. Similarly, Cossío et al. (2021) reported a higher prevalence of monoparasite species (55.5%) in cats, followed by double species (36.7%) and triple concurrent species (14%). This pattern is likely due to the intermittent shedding of ova by some parasites and the possibility that some might have been in a prepatent stage at the time of sample collection, as suggested by Villeneuve et al. (2015).

The identification of *T. cati* as the most common parasite (9.4%) in the present study areas (Table 4) agrees with earlier studies by Romano et al. (2014); Hoggard et al. (2019); Mohmad et al. (2020); Darabi et al. (2021), Genchi et al. (2021); Abbas et al. (2022); Chan et al. (2023) and Widiyono et al. (2023) who reported *Toxocara* as the most prevalent helminth in examined cats. Similarly, Zanzani et al. (2014) noted *Toxocara cati* as the most common parasite detected in different metropolitan areas of Italy, with prevalence rates ranging from 5.6% to 22.4%. However, according to Mukutmoni et al. (2022) and Silva et al. (2023a), hookworms showed the highest prevalences of 9.3% and 67.1%, respectively. Conversely, Nateneal et al. (2015) reported *T. cati* as the least prevalent helminth (1%) in cats from Harar town, Eastern Ethiopia. The high prevalence of *T. cati* compared to other helminths may be attributed to multiple transmission routes to kittens, including via transport/paratenic hosts, transplacental, and transmammary routes, as suggested by (Becker et al., 2012). *Toxocara cati* has immense public health zoonoses and economic implications globally (Macpherson, 2013).

The finding that *D. caninum* is the second most common parasite, with a prevalence of 8.9% in this study, aligns with previous findings by Lorenzini et al. (2007), Romano et al. (2014), Arruda et al. (2021), and Mukutmoni et al. (2022). This association is likely due to the high prevalence of flea infestations, as fleas are the intermediate hosts crucial for the transmission of *D. caninum* to definitive cat hosts (Ramos et al., 2020). On the contrary, Abbas et al. (2022) and Bourgoin et al. (2022) reported *D. caninum* as the least prevalent helminth (0.7%) in cats from Egypt and <3% in cats from France, respectively. Similarly, Nateneal et al. (2015) revealed that *D. caninum* was the least prevalent helminth (2.3%) in cats from Harar town, Eastern Ethiopia. Although human dipylidiasis is rarely reported, the parasite presents significant public health concerns. Infections with this tapeworm occurs if fleas containing the infective cysticercoid stage are ingested by humans (Bowman et al., 2002).

Taenia spp. are another cestode parasites detected in this study with a prevalence of 3.8%, aligns with previous studies by Lorenzini et al. (2007), Hussam (2015), Abbas et al. (2022) and Soe et al. (2023), which reported prevalences of 3.4%, 4.6%, 4.2% and 4.3%, respectively. However, Alimohammad et al. (2011) and Mohmad et al. (2020) reported higher prevalences of 16.2% and 22.5%, respectively, while Jittapalapong et al. (2007) reported a lower prevalence of 0.07%. *Taenia taeniaeformis* is typically the only species of *Taenia* reported from domestic cats worldwide (Bowman et al., 2002). The occurrence of *Taenia* spp. in cats indicates that definitive hosts may acquire infection by scavenging infected hosts (Mohmad et al., 2020).

In cats of this present study, *Giardia* spp. were reported as the most common protozoan parasites (2.8%), followed by *Giardia* trophozoites (2.3%) and *Isospora* spp. (0.5%), which is consistent with previous reports by Alimohammad et al. (2011), Zanzani et al. (2014), Hussam (2015) and Cossío et al. (2021). Whereas Arruda et al. (2021) detected only the coccidia of the genus *Cystoisospora* in both dogs and cats. Previous studies indicate that protozoa infections in cats can occur through the ingestion of food and water contaminated with cysts of protozoa, which are then discharged with their faeces into the environment, playing a major role in the transmission of these parasites to humans (Mamatha et al., 2005). Recent evidence suggests that products released by the parasite can alter gut epithelial permeability through a direct cytopathic effect (Scott et al., 2002).

5. Conclusion and recommendations

The present study demonstrated a high overall prevalence (34.7%) of gastrointestinal parasites in cats. Nematode parasites had the largest share in the monoparasitic infections (14.6%). Statistically significant higher prevalence of gastrointestinal parasites was observed in females, young cats, and cats which consumed uncooked food. Cats that shared shelter with families had a higher prevalence (52.2%) of gastrointestinal parasites. *Toxocara cati* was the most common parasite detected (9.4%), followed by *D. caninum* (8.9%) and *Taenia* spp. (3.8%), suggesting that gastrointestinal parasites are still prevalent enough to affect cats in the study areas, causing mortality and morbidity in these animals, and potentially affecting public health. Parasitic infections in cats could be a significant public health concern; therefore, a One Health approach is essential to tackle this public health threat.

In light of this, further in-depth research is needed to fully understand the economic and zoonotic impact of different gastrointestinal parasites in cats. Detailed epidemiological and molecular investigations to identify the parasites to the species level in larger study areas across different agro-ecologies and seasons should be performed. Furthermore, awareness creation among the general community regarding the occurrence, public health, and economic impact of gastrointestinal parasites in cats is highly recommended.

Ethics approval

The approval on animal handling ethics was received before the commencement of the study. All the animal handling and sample collection methods were performed in accordance with the Addis Ababa University College of Veterinary Medicine Research Ethics (AAU-CVMA-REC) and animal welfare guide for the care and use of animals (Ref. No. VM/ERC/36/02/15/2023).

CRediT authorship contribution statement

Kibruyesfa Bayou: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Getachew Terefe:** Supervision. **Bersissa Kumsa:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

Derived data supporting the findings of this study are available from the corresponding author [BK] on request.

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RESEARCH ARTICLE

Knowledge, attitude, and practices of dog and cat owners toward pet gastrointestinal parasites and associated zoonosis in selected districts of Central Ethiopia

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ABSTRACT

Objective: Ethiopian dog and cat owners' knowledge, practice, and attitude (KAP) regarding gastrointestinal (GI) parasites and related zoonosis in various regions of the nation is yet unclear. The objective of this study was to assess the KAP toward dog and cat gastrointestinal parasites and associated zoonosis.
Materials and Methods: A cross-sectional questionnaire interview survey was conducted on 272 dog and cat owners in Bishoftu, Dukem, and Addis Ababa, central Ethiopia, from February 2022 to April 2023.
Results: The majority, 191 (70.2%), of the study participants were male, and 141 (51.8%) of them fall in the age range of 31–50 years old. According to the survey, 217 (79.8%) of the participants were aware of dog and cat GI parasitic zoonosis, and the majority, 185 (68%), of them were found to think that GI parasitosis is a serious disease. Of the participants, 185 (68%) were aware that pet ownership can pose health risks. The survey disclosed that dog and cat owners had an overall good knowledge (score = 54.6% and 63.9%, respectively), positive attitude (score = 82.1% and 84.1%, respectively), and poor practices (score = 46% and 37.6%, respectively) towards GI parasites of dogs and cats.
Conclusion: Dog and cat owners had good knowledge, a positive attitude, and poor practices regarding GI parasites on dogs and cats. Therefore, dog and cat owners should implement best practices and remain up to date with the latest knowledge for GI parasite prevention and control.

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Introduction

The most tamed pet animals in many nations, including Ethiopia, are dogs and cats [1,2]. Many people view domestic dogs and cats as devoted friends and close companions who love life with people [3]. In terms of socialization and emotional development, this human-animal link can have many beneficial effects. Research has demonstrated the psychological and physical advantages of pet ownership and companionship, especially for young people, the elderly, and people with impaired immune systems [4].

Free-roaming, unregulated dog and cat populations are carriers and reservoirs of numerous zoonotic illnesses in Ethiopia and other parts of the world, particularly gastrointestinal tract protozoa and helminths [3,5,6]. Numerous studies have reported on the incidence of intestinal parasites in dogs in different parts of Ethiopia and the world [7,8]. One of the factors causing parasitic diseases in animals may be the owners' limited awareness of the parasites. To create preventive measures aimed at advancing both human and animal health, with a focus on the One Health approach, it is vital to comprehend how pet owners see zoonotic parasites in relation to pets, namely dogs and cats. This idea consists of multi-sectoral and transdisciplinary cooperative efforts to improve health by better comprehending the relationship between people, animals, and the environment [9].

Although many homes possess pets, there are differing views in the community regarding the proper care of these

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animals [10]. If pet owners do not know about zoonotic disease risks, they would not see the need for preventive measures to reduce hazards [11]. There is a major risk to public health from this lack of awareness of how zoonotic illnesses spread [12]. Numerous zoonosis outbreaks brought on by pet interaction pose a threat to the community. A comprehensive understanding of the attitudes and practices of communities around contact-borne zoonotic illnesses is necessary for the development and use of successful disease prevention and control measures [10].

Therefore, it is essential to comprehend disease epidemiology as well as community knowledge, practices, and attitudes regarding disease transmission routes to develop an effective control program against any disease of public health concern [13]. Identification of the knowledge gap and increasing the awareness and knowledge of the community based on the observed gap and deficiency is considered reliable for making informed interventions that will result in changing attitudes and practices of the society to minimize disease burden. However, there is a lack of sufficient information about the magnitude of zoonotic parasitic disease prevalence among dogs and cats in most parts of Ethiopia [7,14]. So far, little is known about the dog and cat-owning community of Bishoftu, Dukem, and Addis Ababa areas with regard to the management, knowledge, practice, and attitude of dog and cat owners in relation to the potential zoonotic gastrointestinal parasites of their dogs and cats. Therefore, the purpose of this study was to describe the public's knowledge, attitudes, and practices about dog and cat gastrointestinal parasites in central Ethiopia, specifically in Bishoftu, Dukem, and Addis Ababa.

Materials and Methods

Ethical considerations

The Addis Ababa University College of Veterinary Medicine and Agriculture Research Ethics Committee Research Ethics Guide (Ref. No. VM/ERC/36/02/15/2023) was followed in the approval and execution of the current study.

Study area and study design

A cross-sectional questionnaire interview survey was conducted on dog and cat owners in Bishoftu, Dukem, and Addis Ababa in central Ethiopia from February 2022 to April 2023.

Bishoftu town (Ada'a district) is located 47 km from Addis Ababa at an elevation of 1,850 m above sea level, with latitudes 9°N and longitudes 40°E. The region has a bimodal rainfall pattern, with a longer wet season from June to September and a shorter rainy season from March to May. It receives 866 mm of rainfall annually, of which 84% falls during the long rainy season and the remainder during the short one. October through February is considered the dry season. The region experiences 61.3% relative humidity and average annual maximum and minimum temperatures of 26°C and 14°C, respectively [15]. According to species, there are 160,697 cattle, 22,181 sheep, 37,510 goats, 1,660 horses, and 191,380 poultry in the livestock population [16].

Dukem is located close to the main route to Adama, 37 km southeast of Addis Ababa. Between latitudes 8045'25" N and 8050'30" N and longitudes 38051'55" E and 38056'5" E, the study area physically covers 9,630.6 hectares. The average elevation above sea level is 2,100 m. The town is surrounded by the towns of Bishoftu and Gelan in the southeast and most of the north, respectively. The remaining eastern and western parts of the town are bounded by four neighboring Peasant Associations of the Akaki district [17].

At an elevation of 2408 m above sea level, Addis Ababa is located at latitudes 903' North and 38043' East. And 9.4°C and 23.2°C are the average annual lowest and maximum temperatures, respectively. The mean annual rainfall is 1201 mm. Rainfall is bimodal: long, heavy showers from June to September and short, light showers from February to April [18]. There is no statistical information recorded on the dog and cat populations in the study areas.

Data collection

A structured questionnaire interview survey was carried out in Bishoftu, Dukem, and Addis Ababa to evaluate the knowledge, attitude, and practice (KAP) of dog and cat owners regarding their pets' gastrointestinal parasites and associated zoonosis. The study comprised participants who owned simply a dog or cat. Participants (households) in the study had to be at least 18 years old. $N = 0.25/SE^2$ is the formula provided by Arsham [19], where N is the sample size and SE is the standard error. We used a standard error of 0.035 to determine the number of households participating in the questionnaire survey. $N = 0.25/(0.035)^2 = 204$, but a total of 272 households were included in the study. A simple random sampling method was used to select 272 respondents (172 dog owners and 100 cat owners) from the study districts.

We asked randomly chosen respondents for their permission to respond to all survey questions before allowing them to participate. Four components make up the survey's questionnaire. The first part had questions about the owners' demographics, including age, education level, marital status, gender, occupation, length of pet ownership, and reason for keeping the pet. These criteria were anticipated to be the primary determinants of owners' perceived seriousness regarding gastrointestinal parasites in dogs and cats.

The owner's management and practices regarding pet gastrointestinal parasites were the focus of the second section. The following are the points included in this section: issues of animal housing condition, feeding condition, usual place of defecation of dogs and cats, cleaning and disposing of dog and cat excrement, having access to any veterinary service for dogs and cats, using protective equipment during animal house/environment cleaning, having usual contact with dogs and cats, eating raw meat/vegetables, and washing hands before meals.

The third section focused on questions that were related to the owner's general knowledge about gastrointestinal parasites of dogs and cats as follows: knowing what gastrointestinal intestinal parasites are, dogs/cats can have gastrointestinal parasites, any clinical sign of gastrointestinal parasite infection in dogs and cats, the mode of transmission of gastrointestinal parasites from animal to animal, how to control/prevent gastrointestinal parasites in dogs and cats, any gastrointestinal parasites of dogs and cats that can be transmitted to humans, and knowing the mode of transmission of gastrointestinal parasites from pet to man.

The fourth section focused on questions that were related to the owner's general attitude about gastrointestinal parasites of dogs and cats as follows: thinking of gastrointestinal parasitosis as a serious disease, the health risk of pet ownership, the risk of getting gastrointestinal parasitosis by playing with dogs/cats, feeding raw food to dogs and cats can cause gastrointestinal parasitosis, washing hands with water and soap hinders the transmission of gastrointestinal parasites to humans, medication/treatment is necessary when dogs and cats experience gastrointestinal parasitosis, and thinking health education can reduce gastrointestinal parasite prevalence.

Determining KAP scores

There are two types of questions to measure the level of KAP regarding gastrointestinal parasites of dogs and cats, with some questions having one ("yes" or "no" answer) or more possible answers, which were given one point for a correct response and zero points for an uncertain or "don't know" response. The other type of questions had open-ended answers, representing poor, fair, and good levels of KAP. A higher score indicated a greater understanding of gastrointestinal parasites in dogs and cats. The overall knowledge score varied from 0% to 100%. The cut-off value for the KAP score level was determined by the participant's capacity to define gastrointestinal intestinal parasites, knowing clinical signs, mode of transmission, control, and prevention of these parasites in dogs/cats, appropriate management and practices, and level of their attitude towards gastrointestinal parasites of their dog/cat. The questionnaire consisted of 26 questions in total, and an average KAP score of 50% or higher was deemed to indicate "good knowledge," which denotes an adequate understanding of gastrointestinal parasites in cats and dogs. Conversely, "poor knowledge," which denotes inadequate knowledge, was defined as having an average KAP scale of less than 50%. Similarly, "positive attitude," "negative attitude," "good practice," and "poor practice" were categorized using a comparable scoring method that was modified from [20,21].

Statistical analysis

The Microsoft Excel sheet 2010 was used to enter all of the generated data. IBM SPSS version 27 was used to analyze the data. Univariate descriptive analysis was used to determine the frequencies, percentages, and statistical significance between different independent variables. The relationship between each independent variable and the dependent variables is then evaluated using a bivariate analysis, with only potential predictors with a *p*-value less than 0.25 being considered for the multivariate analysis to assess the level of animal owners' knowledge about gastrointestinal parasites of their dog and cat. Additionally, the average knowledge, average attitude, and average practices, along with their standard deviations for each independent variable (socio-demographic characteristics), were calculated and then analyzed to see how each independent variable relates to the dependent variables. We deemed it statistically significant when the *p*-value was less than 0.05.

Results

Socio-demographic characteristics of dog and cat owners

This study included a total of 272 respondents (172 dog owners and 100 cat owners) from Bishoftu, Dukem, and Addis Ababa. Out of this, 70.2% were males and 29.8% were females. The majority, 51.8% of the study participants, fall within the age category of 31–50 years old, followed by 30.9% in the age group of greater than 50 years, and 68.4% of them were married. Based on education level, 36.8% of the respondents were non-formal education/illiterate, followed by secondary school graduates and college/university level with proportions of 25.4% and 22.8%, respectively. Finally, 38.2% of the respondents were in the profession of livestock/poultry keeping, and this was followed by proportions of 32.4% and 22.1% of civil servants and merchants, respectively (Table 1).

Management and practices of dog and cat owners toward gastrointestinal parasites

From the total respondents, the majority of them kept their pets free outdoors and fed their pets raw offal/

Table 1. Socio-demographic characteristics of dog and cat owners.

Variable	Category	Total frequency (%)	Dog Owners (*n* = 172) *N* (%)	Cat Owners (*n* = 100) *N* (%)
Districts	Bishoftu	136 (50)	86 (50)	50 (50)
	Dukem	50 (18)	0 (0.0)	50 (50)
	Addis Ababa	86 (31.6)	86 (50)	0 (0.0)
Sex	Male	191 (70.2)	120 (69.8)	71 (71)
	Female	81 (29.8)	52 (30.2)	29 (29)
Age	15–30 years	47 (17.3)	30 (17.4)	17 (17)
	31–50 years	141 (51.8)	88 (51.2)	53 (53)
	> 50 years	84 (30.9)	54 (31.4)	30 (30)
Marital status	Single	81 (29.8)	58 (33.7)	28 (28)
	Married	186 (68.4)	114 (66.3)	72 (72)
Education level	Non-formal education/ Illiterate	100 (36.8)	66 (38.4)	34 (34)
	Primary school	41 (15.1)	26 (15.1)	15 (15)
	Secondary education	69 (25.4)	42 (24.4)	27 (27)
	College/University	62 (22.8)	38 (22.1)	24 (24)
Occupation	Crop farming	20 (7.4)	14 (8.1)	6 (6)
	Livestock/poultry keeping	104 (38.2)	66 (38.4)	38 (38)
	Civil servant/ Professional	88 (32.4)	52 (30.2)	36 (36)
	Merchant	60 (22.1)	40 (23.3)	20 (20)

N, number; %, percentage.

meat/milk, followed by scavenging, condemned offal and human food, and cooked offal/meat/milk. Among the respondents, the majority of the cats' and dogs' owners were found to clean pets' excrement and dispose of it into the toilet by taking the necessary precautions while cleaning the dog and cat houses/environment. Of the total respondents, 30.2% and 8% of the dog and cat owners brought their pets to a veterinary clinic to deworm their dogs and cats, respectively. The majority of the respondents had no usual contact with their dog/cat and had experience of consuming cooked meat/vegetables, and all of them had experience of washing their hands before a meal. The average KAP score of dog and cat owners' practices towards gastrointestinal parasites of their dog/cat was found to be 46% and 37.6% for dog and cat owners, respectively, which indicated that the dog and cat owners had bad practices toward gastrointestinal parasites of dog/cat (Table 2).

Knowledge of dog and cat owners toward gastrointestinal parasites and their associated zoonosis

Of the respondents in this study, 52.9% of them were found to have an awareness of what gastrointestinal parasites are, and 61.8% knew that dogs and cats can have gastrointestinal parasites. *Ascarids* and *cestodes* were the main parasites mentioned by dog and cat owners with 23.5% and 12.1% proportions, respectively. The present study revealed that 57.7% of the interviewees had knowledge of clinical signs of gastrointestinal parasite infection in dogs and cats. Concerning the mode of transmission of gastrointestinal parasites from animal to animal, 60.7% of the animal owners indicated that they knew the main mechanisms of transmission, and fecal contamination and contact with infected ones were mentioned as the main mechanisms of transmission with proportions of 23.2% and 37.5%, respectively.

Cleaning the environment, cleaning and disinfection, feeding cooked meat/offal/milk, and deworming pets regularly were mentioned as the main mechanisms to control/prevent parasites among dogs and cats with a proportion of 28.7%, 15.4%, 12.1%, and 6.3%, respectively. This questionnaire interview survey revealed that 79.8% of the respondents were aware of dog and cat gastrointestinal parasitic zoonosis, and *Toxocara* spp. and *Taenia* spp. were mentioned by the animal owners as main gastrointestinal parasites that have zoonotic importance with

Table 2. Management and practices of dog and cat owners towards gastrointestinal parasites (*n* = 272).

Variable	Category	Total Frequency (%)	Dog Owners (*n* = 172) N (%)	KAP Score (%) of Dog Owners	Cat Owners (*n* = 100) N (%)	KAP Score (%) of Cat Owners	*p*-value
Housing to your dog/cat	Kennel/ leashed	25 (9.2)	24 (14**)	14	1 (1**)	1	<0.002*
	Free outdoor	159 (58.5)	90 (52.3)		69 (69)		
	Free in home/compound	88 (32.4)	58 (33.7)		30 (30)		
Feed of your dog/cat	Cooked meat/offal/milk	34 (12.5)	22 (12.8**)	12.8	12 (12**)	12	0.597
	Raw meat/offal/milk	133 (48.9)	80 (46.5)		53 (53)		
	Scavenging	57 (21)	38 (22.1)		19 (19)		
	Condemned offals and human food left over	48 (17.6)	32 (18.6)		16 (16)		
Usual place of defecation of your dog/cat	In public field	107 (39.3)	64 (37.2)		43 (43)		<0.002*
	In their cage only	25 (9.2)	24 (14**)	14	1 (1**)	1	
	In the compound/ground/	140 (51.5)	84 (48.8)		56 (56)		
Cleaning and disposing your dog's/cat's excrement	Clean and bury in the ground	33 (12.1)	22 (12.8)		11 (11)		0.297
	Clean and add to the toilet	126 (46.3)	84 (48.8**)	48.8	42 (42**)	42	
	Clean and dispose with house garbage	74 (27.2)	40 (23.3)		34 (34)		
	Do not clean	39 (14.3)	26 (15.1)		13 (13)		
Access to any veterinary service for your dog/cat	Yes	134 (49.3)	96 (55.8**)	55.8	38 (38**)	38	<0.005*
	No	138 (50.7)	76 (44.2)		62 (62)		
Veterinary service you have/had for your dog/ cat	Vaccination	17 (6.3)	12 (6.9)		5 (5)		<0.001*
	Deworming	60 (22.1)	52 (30.2**)	30.2	8 (8**)	8	
	Spaying/neutering	21 (7.7)	16 (9.3)		5 (5)		
	Other services	20 (7.4)	16 (9.3)		4 (4)		
	No service	154 (56.6)	76 (44.2)		78 (78)		
Use protective equipment (like glove, facemasks, boots, gown) during cleaning	Yes	143 (52.6)	96 (55.8**)	55.8	47 (47**)	47	0.160
	No	129 (47.4)	76 (44.2)		53 (53)		
Have usual contact with your dog/cat	Yes	103 (37.9)	62 (36)		41 (41)		0.417
	No	169 (62.1)	110 (64**)	64	59 (59**)	59	
Eat raw meat/vegetable	Yes	92 (33.8)	60 (34.9)		32 (32)		0.628
	No	180 (66.2)	112 (65.1**)	65.1	68 (68**)	68	
Wash your hand before meal	Yes	272 (100)	172 (100**)	100	100 (100**)	100	
	No	0 (0.0)					
Average KAP score of dog and cat owners' practices toward gastrointestinal parasites of their dog/cat				46		37.6	

Note: *Represent statistically significant difference ($p \leq 0.05$); ** Proportion considered as KAP score. *N*, number; %, percentage.

a proportion of 8.5% and 9.9%, respectively. Eating raw meat/vegetables, fecal contamination, and contact with infected pets were mentioned by animal owners as the main modes of transmission of the parasites to humans. The average KAP score of dog and cat owners' knowledge toward gastrointestinal parasites of their dog/cat was found to be 54.6% and 63.9% for dog and cat owners, respectively, which indicated that the dog and cat owners had good knowledge toward gastrointestinal parasites of their dog/cat (Table 3).

Table 3. Knowledge of dog and cat owners towards gastrointestinal parasites and their associated zoonosis (n = 272).

Variable	Category	Total Frequency (%)	Dog Owners (n = 172) N (%)	KAP Score (%) of Dog Owners	Cat Owners (n = 100) N (%)	KAP Score (%) of Cat Owners	p-value
Know what gastrointestinal intestinal parasites are	Yes	144 (52.9)	90 (52.3**)	52.3	54 (54**)	54	0.790
	No	128 (47.1)	82 (47.7)		46 (46)		
Know that dogs/cats can have gastrointestinal parasites	Yes	168 (61.8)	108 (62.8**)	62.8	60 (60**)	60	0.648
	No	104 (38.2)	64 (37.2)		40 (40)		
Gastrointestinal parasites of dogs/ cats which you know	*Ascarids*	64 (23.5)	50 (29.1)		14 (14)		0.011*
	Cestodes	33 (12.1)	22 (12.8)		11 (11)		
	No parasites	175 (64.3)	100 (58.1)		75 (75)		
Know any clinical sign of gastrointestinal parasites infection in dogs/cats	Yes	157 (57.7)	100 (58.1**)	58.1	57 (57**)	57	0.854
	No	115 (42.3)	72 (41.9)		43 (43)		
If yes for above question, main clinical signs	Diarrhoea	49 (18)	28 (16.3)		21 (21)		0.770
	Vomiting	29 (10.7)	18 (10.5)		11 (11)		
	Weight loss	47 (17.3)	28 (16.3)		19 (19)		
	Inappetence	18 (6.6)	12 (6.9)		6 (6)		
	Do not know	129 (47.4)	86 (50)		43 (43)		
Know the mode of transmission of gastrointestinal parasites from animal to animal	Yes	165 (60.7)	106 (61.7**)	61.7	59 (59**)	59	0.669
	No	107 (39.3)	66 (38.4)		41 (41)		
If yes for above question, main modes of transmission	*Fecal* contamination	63 (23.2)	40 (23.3)		23 (23)		0.589
	Contact with infected ones	102 (37.5)	68 (39.5)		34 (34)		
	Do not know	107 (39.3)	64 (37.2)		43 (43)		
Know how to control/prevent gastrointestinal parasites in dogs/ cats	Yes	170 (62.5)	104 (60.5**)	60.5	66 (66**)	66	0.363
	No	102 (37.5)	68 (39.5)		34 (34)		
If yes for above question, mention main mechanisms to control/ prevent the parasites	Cleaning the environment	78 (28.7)	52 (30.2)		26 (26)		<0.001*
	Cleaning and disinfection	42 (15.4)	28 (16.3)		14 (14)		
	Feeding cooked meat/offal	33 (12.1)	22 (12.8)		11 (11)		
	Deworming regularly	17 (6.3)	15 (8.7)		2 (2)		
	Do not know	102 (37.5)	68 (39.5)		34 (34)		
Observe a parasite or segment of parasite in dog/cat excrement	Yes	76 (27.9)	76 (44.2)		0 (0.0)		<0.001*
	No	196 (72.1)	96 (55.8)		100 (100)		
Know any gastrointestinal parasites of dogs/cats that can be transmitted to humans	Yes	217 (79.8)	136 (79.1**)	79.1	81 (81**)	81	0.702
	No	55 (20.2)	36 (20.9)		19 (19)		
If yes for above question, mention some parasites	*Toxocara* spp.	23 (8.5)	14 (8.1)		9 (9)		0.907
	Taenia spp.	27 (9.9)	18 (10.5)		9 (9)		
	No parasite	222 (81.6)	140 (81.4)		82 (82)		
Know the mode of transmission of gastrointestinal parasites from pet to man?	Yes	190 (69.9)	120 (69.8**)	69.8	70 (70**)	70	0.968
	No	82 (30.1)	52 (30.2)		30 (30)		

Continued

Variable	Category	Total Frequency (%)	Dog Owners (*n* = 172)	KAP Score (%) of Dog Owners	Cat Owners (*n* = 100)	KAP Score (%) of Cat Owners	*p*-value
			N (%)		*N* (%)		
If yes for above question, main modes of transmission	Contact with infected pet	124 (45.6)	76 (44.2)		48 (40)		0.875
	Fecal contamination	29 (10.7)	18 (10.5)		11 (11)		
	Eating raw meat/ vegetable	29 (10.7)	18 (10.5)		11 (11)		
	Do not know	90 (33.1)	60 (34.9)		30 (30)		
Average KAP score of dog and cat owners Knowledge toward gastrointestinal parasites of their dog/cat				54.6		63.9	

Note: *Represent statistically significant difference ($p \leq 0.05$); **: Proportion considered as KAP score. *N*, number; %, percentage.

Table 4. Attitude of dog and cat owners towards gastrointestinal parasites and their associated zoonosis.

Variable	Category	Total frequency (%)	Dog Owners (*n* = 172)	KAP Score (%) of Dog Owners	Cat Owners (*n* = 100)	KAP score (%) of cat owners	*p*-value
			N (%)		*N* (%)		
Gastrointestinal parasitosis is a serious disease	Yes	185 (68)	114 (66.3*)	66.3	71 (71*)	71	0.421
	No	87 (32)	57 (33.1)		30 (30)		
Pet ownership can have health risk	Yes	185 (68)	116 (67.4*)	67.4	69 (69*)	69	0.422
	No	87 (32)	60 (34.9)		27 (27)		
Playing with dog/cat may expose to gastrointestinal parasitosis	Yes	185 (68)	114 (66.3*)	66.3	71 (71*)	71	0.421
	No	87 (32)	58 (33.7)		29 (29)		
Feeding raw food to dog/cat can cause gastrointestinal parasitosis	Yes	236 (86.8)	148 (86*)	86	88 (88*)	88	0.647
	No	36 (13.2)	24 (14)		12 (12)		
Washing hands with water and soap hinder the transmission of gastrointestinal parasites to humans	Yes	257 (94.5)	162 (94.2*)	94.2	95 (95*)	95	0.777
	No	15 (5.5)	10 (5.8)		5 (5)		
Medication/treatment is necessary when your dog/cat experience gastrointestinal parasitosis	Yes	263 (96.7)	166 (96.5*)	96.5	97 (97*)	97	0.828
	No	9 (3.3)	6 (3.5)		3 (3)		
Health education can reduce gastrointestinal parasite prevalence	Yes	266 (97.8)	168 (97.7*)	97.7	98 (98*)	98	0.860
	No	6 (2.2)	4 (2.3)		2 (2)		
Average KAP score of dog and cat owners' attitude toward gastrointestinal parasites of their dog/cat				82.1		84.1	

Note: *Proportion considered as KAP score. *N*, number; %, percentage.

Attitude of dog and cat owners toward gastrointestinal parasites and their associated zoonosis

Of the respondents in this study, 68% of them were found to think that gastrointestinal parasitosis is a serious disease. Regarding owners' perception about health risk to the human, it showed that 68% of them were found to have awareness, and they indicated that pet ownership can have health risks. According to the response of animal owners, playing with dogs and cats and feeding raw food to dogs and cats were found to expose them to gastrointestinal parasitosis in men and animals with the proportions of 68% and 86.8%, respectively. Among owners, 94.5% of them indicated that washing hands with water and soap hinders the transmission of gastrointestinal parasites to humans, and 96.7% of the respondents informed that medication/treatment is necessary when dogs and cats experience gastrointestinal parasitosis. The average KAP score of dog and cat owners' attitude towards gastrointestinal parasites of their dog/cat was found to be 82.1% and 84.1% for dog and cat owners, respectively, which indicated that the dog and cat owners had a positive attitude towards gastrointestinal parasites of their dog/cat (Table 4).

Table 5. Mean knowledge, attitude and practices scores across socio-demographic characteristics.

Variable	Category	Mean knowledge dcore		Mean attitude score		Mean practice score	
		Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation
Districts	Bishoftu	1.65	0.39	1.19	0.24	2.17	0.26
	Dukem	1.4	0.32	1.11	0.17	2.31	0.17
	Addis Ababa	1.58	0.38	1.19	0.24	2.12	0.24
p-value		<0.001*		0.125		<0.001*	
Sex	Male	1.51	0.39	1.15	0.23	2.19	0.26
	Female	1.74	0.34	1.21	0.24	2.15	0.21
p-value		<0.001*		0.066		0.148	
Age	18-30 yrs.	1.35	0.36	1.07	0.15	2.22	0.22
	31-50 yrs.	1.49	0.35	1.17	0.22	2.11	0.21
	> 50 yrs.	1.87	0.29	1.23	0.27	2.23	0.28
p-value		<0.001*		<0.001*		<0.001*	
Marital status	Single	1.56	0.42	1.16	0.26	2.25	0.23
	Married	1.59	0.38	1.17	0.21	2.14	0.25
p-value		0.557		0.912		<0.001*	
Education level	Non-formal education/ Illiterate	100	1.82	0.24	1.19	0.25	2.19
	Primary school	41	1.80	0.34	1.26	0.26	2.22
	Secondary school	69	1.43	0.33	1.21	0.20	2.08
	College/University	62	1.26	0.15	1.01	0.03	2.19
p-value		<0.001*		<0.001*		0.004*	
Occupation	Crop farming	1.84	0.29	1.41	0.34	2.38	0.21
	Livestock/poultry keeping	1.87	0.27	1.24	0.22	2.21	0.24
	Civil servant/ Professional	1.27	0.28	1.05	0.15	2.13	0.25
	Merchant	1.44	0.29	1.15	0.19	2.13	0.21
p-value		<0.001*		<0.001*		<0.001*	

Note: *Represent statistically significant difference ($p \leq 0.05$). Std. Deviation, Standard deviation.

Mean knowledge, attitude, and practices across the socio-demographic characteristics

The mean knowledge score was higher (1.65 + 0.39) for Bishoftu than for other districts. The mean attitude score was similar for Bishoftu and Addis Ababa (1.19 + 0.24), which is higher than the score recorded for Dukem (1.11 + 0.17). However, the mean practice score was higher (2.31 + 0.17) for Dukem than for other districts. The study found that females had higher mean scores of 1.74 + 0.34 and 1.21 + 0.24 than males for knowledge and attitudes, at $p < 0.001$ and $p = 0.066$, respectively, whereas males had higher mean scores of 2.19 + 0.26 than females for practice at $p = 0.148$. The age group greater than 50 had a higher mean score of knowledge, attitude, and practice (1.87 + 0.29, 1.23 + 0.27, and 2.23 + 0.28, respectively, at $p < 0.001$). Additionally, mean scores statistically differed among different education level groups and among different occupation categories (Table 5).

Analysis of the association between gastrointestinal parasites of dogs and cats, knowledge of participants, and potential predictors of knowledge

At a cutoff point of 50% and higher, the survey discovered that roughly 52.9% (144/272) of participants knew about gastrointestinal parasites of dogs and cats. To evaluate the relationship between the knowledge and the possible predictors, Pearson chi-square was used. There was an association between knowledge and the observed level of owners knowledge of whether they know dogs/cats can have gastrointestinal parasites or not (χ^2=76.804, p = 0.001); on clinical signs (χ^2 = 77.857, p = 0.001); mode of transmission (χ^2 = 54.354, p = 0.001); know how to

Table 6. Summary of univariate regression analysis of potential predictors within the knowledge category and the observed level of knowledge about gastrointestinal parasites of dog and cat.

Variable	Category	Number of Participants (*n* = 272)	Knowledgeable (*n* = 144)	Proportion(%)	OR	95% CI	*p*-value
What gastrointestinal intestinal parasites are**	Yes	144	126	87.5	Ref		<0.001*
	No	128	18	14.1	0.247	0.540–0.178	
Dogs/cats can have gastrointestinal parasites**	Yes	168	124	73.8	Ref		
	No	104	20	19.2	0.084	0.047–0.153	<0.001*
Any clinical sign of gastrointestinal parasites infection in dogs/cats**	Yes	157	119	75.8	Ref		
	No	115	25	21.7	0.089	0.050–0.158	<0.001*
Mode of transmission of gastrointestinal parasites from animal to animal**	Yes	165	117	70.9	Ref		<0.001*
	No	107	27	25.2	0.138	0.080–0.240	
Know how to control/prevent gastrointestinal parasites in dogs/cats**	Yes	170	126	74.1	Ref		<0.001*
	No	102	18	17.6	0.075	0.040–0.138	
Gastrointestinal parasites of dogs/cats that can be transmitted to humans**	Yes	217	135	62.2	Ref		<0.001*
	No	55	9	16.4	0.119	0.055–0.255	
Know the mode of transmission of gastrointestinal parasites from pet to man**	Yes	190	129	67.9	Ref		<0.001*
	No	82	15	18.3	0.106	0.056–0.200	

Note: *Significant at 0.05, considered for multivariate analysis; **considered for multivariate analysis (cut-off *p* 0.250). n, number of participants; CI, Confidence interval; OR, Odds ratio; %, percentage; Ref, reference category.

control/prevent gastrointestinal parasites (χ^2 = 81.600, p = 0.001); know any gastrointestinal parasites of dogs/cats that can be transmitted to humans (χ^2 = 37.023, p = 0.001) and whether they know the mode of transmission of gastrointestinal parasites from pet to man (χ^2 = 56.567, p = 0.001). Univariate linear regression was then used to screen the variables for multicollinearity (Table 6).

Predictors of the participants knowledge about gastrointestinal parasites

Following the stepwise binary logistic regression model's correction for other variables, participants' knowledge of dog and cat gastrointestinal parasites was significantly predicted by a p-value < 0.05. Variables with a p-value < 0.250 in the bivariate analysis were included in the model. The test had an insignificant Hosmer-Lemeshow goodness-of-fit statistic, and the Omnibus Test of Model Coefficients values of p < 0.000 were obtained, indicating the goodness of fit of the generated model. All mentioned variables were found to be significant predictors of participants' knowledge about gastrointestinal parasites of dogs and cats, and Table 7 displays the corresponding adjusted odds ratios (AORs).

Discussion

In this survey, from the total of 272 respondents [172 (63.2%) dog owners and 100 (36.8%) cat owners], 191 (70.2%) were males and 81 (29.8%) were females, and the age group of 31–50 years old was the majority, 141 (51.8%). To the contrary, a study conducted in Western Ethiopia by [22] recorded that 54.6% of the study participants were females, 67.1% of them were dog owners, 7.1% were cat owners, and the rest, 25.8% of them, were both dog and cat owners. Similarly, a study conducted by Urgel et al. [23] in Cebu, Philippines, on 130 dog owners showed that most respondents were female (65.4%), and 55.4% of the owners were in the age range of 18–24 years old. In Brazil, a study by Arruda et al. [24] revealed that they questioned more dog owners than cat owners. Dog owners' greater adherence to epidemiological and community-based studies may have been caused by a number of variables, including the numerical superiority of urban dog populations and their greater prevalence as companion animals [24].

It is quite challenging to describe pet management practices in Ethiopia, mostly because they are not strictly regulated by cleanliness standards. The evidence suggests that there is a very high chance that people will contract zoonotic diseases linked to pet contact. Furthermore, letting dogs run loose both inside and outside the house would encourage the spread of illnesses linked to pets [25]. In the current survey, the majority (58.5%) of the dog and cat owners kept their pets free outdoors, from which 52.3% and 69% were dog and cat owners, respectively. This finding is in line with the previous report of [26], who indicated that 12.4% of the dogs were housed indoors, while 78.6% were free (in both indoor and

Table 7. Summary of maximum-likelihood estimates for predictors associated with participants knowledge about gastrointestinal parasites of dog and cat.

Variable	Category	AOR	95% CI	*p*-value
Know what gastrointestinal intestinal parasites are	Yes	Ref		<0.001*
	No	2.132	1.150–2.158	
Dogs/cats can have gastrointestinal parasites	Yes	Ref		
	No	2.818	1.057–4.153	<0.001*
Know any clinical sign of gastrointestinal parasites infection in dogs/cats	Yes	Ref		<0.001*
	No	3.132	0.150–2.158	
Know the mode of transmission of gastrointestinal parasites from animal to animal	Yes	Ref		<0.001*
	No	2.437	0.080–1.240	
Know how to control/prevent gastrointestinal parasites in dogs/cats	Yes	Ref		<0.001*
	No	13.364	7.232–24.692	
Know any gastrointestinal parasites of dogs/cats that can be transmitted to humans	Yes	Ref		<0.001*
	No	8.415	3.915–18.088	
Know the mode of transmission of gastrointestinal parasites from pet to man	Yes	Ref		<0.001*
	No	9.446	4.994–17.866	

Note: *Significant at 0.05. AOR, adjusted Odds ratio; CI, Confidence interval; Ref, reference category.

outdoor systems). Similarly, 19.5% of the owners had the experience of keeping their dogs in confined (indoor), whereas 36.4% and 42.9% of them kept their dogs outdoors (freely) and semi-confined, respectively [27]. To the contrary, 100% of the dog owners shared the same house with their dogs and livestock [28].

Regarding feeding practices, there is a significant zoonotic danger associated with the growing popularity of raw feed for companion animals. Pathogenic microorganisms have contaminated these diets and their ingredients [25]. In the current survey, most respondents (48.9%) fed their pets raw offal/meat/milk. This finding is in line with the previous report of [27] that the respondents fed their dogs raw animal products, cooked animal products, household leftovers, and a mix of raw animal products and household leftovers with proportions of 12.9%, 2.6%, 58.4%, and 25.9%, respectively. Similarly, 83.7% of the dog owners fed uncooked offal to their dogs [29].

Among the respondents, 84 (48.8%) of the dogs' and 42 (42%) of the cats' owners were found to clean pets' excrement and dispose of it in the toilet, and 143 (52.6%) of them had experience using protective equipment while cleaning the dog and cat houses/environment. However, none of the people cleaning the kennels were following the required measures, and only 11.4% of the families disposed of the dog feces in their toilets [26]. Whereas 47.9% of owners disposed of dogs' feces with household garbage and 88.6% of dog owners cleaned and disposed of the excreta without using necessary precautions for personal protection [29].

Similarly, most dog owners were found to dispose of their dogs' waste with the household's garbage, and only 10% of the individuals were taking the necessary precautions while cleaning the kennel [27]. The risk of zoonotic transmission can be decreased, and the spread of gastrointestinal parasites can be stopped by owners who routinely clean the areas, especially those contaminated with feces [30].

Regarding getting access to any veterinary services in the current study, 49.3% of the respondents had access to veterinary services (like deworming services) for their dogs and cats. However, in other studies, the majority of the respondents had not accessed regular veterinary services for their dog and cat [22]. A study conducted by Mitiku et al. [29] revealed that respondents had deworming services with 58.6% proportions in Bishoftu town. Deworming, which has been advised every 3–6 months, is essential for preventing gastrointestinal parasites. Deworming dogs more frequently than every 6 months increases their risk of contracting gastrointestinal parasites. Generally speaking, the owner's management and deworming procedures can have an impact on gastrointestinal parasite infections in dogs and cats [12].

Among the respondents in this survey, 37.9% of them had usual contact with their dog and cat, whereas 33.8% had experience of feeding raw meat/vegetables, and all of them (100%) had experience of washing hands before meals. To the contrary, 82.9% of the respondents had physical contact with their dog and cat. From the One Health perspective, this set of practices reported by the interviewed owners is of paramount importance, since they can contribute to interrupting the transmission of zoonotic parasites between humans and animals, mainly those featured by passive oral infection, such as *Giardia duodenalis*, *Toxoplasma gondii*, *Cryptosporidium* sp., and *Toxocara* sp., and those featured by active skin infection, such as hookworms [24].

From the respondents in this study, the majority (52.9%) of them were found to have the awareness of what gastrointestinal parasites are, and the majority (61.8%) of them knew that dogs and cats can have gastrointestinal parasites, and *Toxocara* spp. and *Taenia* spp. (with proportions of 23.5% and 12.1%, respectively) were the main parasites mentioned by the dog and cat owners. This finding is in line with the previous report of [29] that 73.6% of the respondents knew that dogs could have gastrointestinal parasites. To a higher level than the current survey, *Taenia* spp. (68.3%) and *Toxocara canis* (31.7%) were the main parasitic diseases of dogs. Similarly, in one study, *Taenia* spp. (56%) and *T. canis* (44%) were the main parasites of dogs mentioned by the respondents [28].

In this survey, the majority (68%) of the respondents indicated that pet ownership can have health risks, and the majority (79.8%) of the respondents were aware of gastrointestinal parasitic zoonosis in dogs and cats. This finding is in line with the previous report of [23] that the majority (42.3%) of respondents were aware that gastrointestinal parasites can be transmitted to humans. According to a survey conducted in the Ethiopian town of Ambo, 44.3% of dog owners were aware of how dogs might spread diseases to people. Sharing a home with dogs, playing with dogs, inadequate management practices, limited dog owners' awareness about dog parasites, and a lack of veterinary care can all increase the risk of spreading canine parasitic zoonoses to the general public [26].

Conclusion

This survey revealed that most of the respondents knew that dogs and cats can acquire gastrointestinal parasites, and some of these gastrointestinal parasites of dogs and cats can be transmitted to humans. The majority of the respondents were found to think that dog and cat ownership can have health risks and that medication/treatment is necessary when dogs and cats experience gastrointestinal parasitosis. The present questionnaire survey disclosed that dog and cat owners had good knowledge, a positive attitude, and poor practices regarding gastrointestinal parasites of dogs and cats. Finally, effective prevention and control of gastrointestinal parasites in dogs and cats require improved awareness among pet owners about the health impact of those parasites on animals and humans. Therefore, dog and cat owners should implement best practices and remain up to date with the latest knowledge and products for gastrointestinal parasite prevention and control.

List of abbreviations

AORs, Adjusted odds ratios; °C, degree Celsius; GI, Gastrointestinal; KAP, Knowledge, attitude, and practice; km, Kilometers; m, Meters; mm, Millimeter; N, sample size; SE, standard error.

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Conflict of interest

There is no conflict of interest, according to the authors.

Authors' contributions

K.B. (Conceptualization, design, data curation, methodology, formal analysis, investigation, and writing), B.K. (Conceptualization, design review, editing, and supervision), G.T. (Review and supervision). Every author gave the work a critical evaluation and gave their approval to the final draft.

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