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Knowledge, attitudes, and perception of dog owners on the transmission, control and prevention of cystic echinococcosis and other gastrointestinal parasites in dogs of Southern provinces of Mozambique

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Abstract
In rural communities of Mozambique, dogs are utilized not only as companion animals, but also for shepherding livestock, guarding, and hunting purposes, increasing exposure of humans to zoonotic parasites. Thus, we conducted a study to assess knowledge, attitudes, and perceptions of rural dog owners living in the districts of Gaza and Inhambane provinces, south of Mozambique, on cystic echinococcosis (CE) followed by a survey on the prevalence of gastrointestinal parasites with emphasis on Taeniidae infection in dogs from the same districts. A structured questionnaire was administered to 335 dog owners to assess their knowledge, attitudes and perceptions related to the risk factors for transmission, control, and prevention of CE. Responses were analyzed with SPSS software using the Chi-square test. To determine the prevalence of endoparasites, 723 dog fecal samples were collected and processed using a flotation technique to detect helminths/protozoa eggs/cysts/oocysts and modified Ziehl Neelsen staining to detect *Cryptosporidium* oocysts. Samples positive for taeniids were further processed to identify them to species level using molecular techniques. 3% (10/335) of respondents of the questionnaire were aware of CE which was higher in males (2.7%; 9/335) compared to females, in respondents aged 26–45 years old (2.1%; 7/335), and in agro-pastoralists (1.8%; 6/335). An overall prevalence of 93.7% (678/723) for at least one parasite species was found. Prevalence was 7.6% (55/723) for *Spirocerca* spp., 50.9% (368/723) for *Ancylostoma* spp., 4% (29/723) for *Toxocara* spp., 5.4% (39/723) for *Trichuris* spp., 8.7% (63/723) for *Sarcocystis* spp., 8.4% (61/723) for *Dipylidium caninum*, 8.7% (63/723) for *Isospora* spp., 2.2% (16/723) for *Giardia* spp. and 1.7% (12/723) for *Cryptosporidium* spp. Prevalence of taeniids was 2.4% (17/723) with six isolates identified as *Taenia hydatigena* and two as *Taenia multiceps*. Results of questionnaire survey showed that the Knowledge of cystic echinococcosis in districts of southern Mozambique was limited, and we recommend the development of targeted public health campaigns to raise awareness of local communities about transmission cycles and prevention CE.

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Future epidemiological studies should be conducted to investigate the potential source of CE infections in cattle by screening both wild and domestic canids.

Keywords Dogs, Gastrointestinal parasites, *Echinococcus granulosus*, *Taenia hydatigena*, *Taenia multiceps*, Zoonotic parasites; Mozambique

Introduction

Cohabitation between humans and dogs is associated with increasing risk of circulation and transmission of food and waterborne zoonotic helminths and protozoa with significant public health problems [1, 2]. Such helminths include members of the Taeniidae family namely *Echinococcus*, *Taenia*, *Hydatigena* and *Versteria* [3]. *Echinococcus granulosus* sensu lato, *E. multilocularis* are the causative agents of cysts and alveolar echinococcosis respectively [4]; while *Taenia serialis* and *T. multiceps* causes of coenurosis in humans and small ruminants [5, 6]. The Dipylidiidae family consists of *Dipylidium caninum* which cause dipylidiosis [7–9].

In low-income countries with extensive sheep breeding, poor resources, and limited health and veterinary care, attention has been given to cystic echinococcosis (CE) which remains a public health issue [10–13]. CE is a financial and economic constraint due to hospital costs for humans and condemnation of infected organs mainly the liver and lungs in slaughterhouses during meat inspection [4, 14, 15]. In dogs and humans, the infection is usually subclinical and asymptomatic even in heavy infections [16]. Transmission cycles consist of dogs accessing raw and infected offals, whilst humans and livestock can be infected when they have access to taeniid eggs from drinking contaminated water or ingestion of contaminated raw vegetables/ pastures. Risk factors for CE include dog ownership together with livestock, slaughter at home, feeding dogs with contaminated offals, poor sanitation, living in rural areas and younger age [17].

The geographical distribution of echinococcosis is cosmopolitan and has been reported in all continents except Antarctica. In sub-Saharan Africa, high prevalence rates have been reported in northern and eastern African countries [18–20] compared to southern African countries [21]. Regarding species and genotypes, *E. granulosus sensu stricto* (G1, G3) is reported to be more prevalent in East Africa; *E. canadensis* (G6/7) in North and West Africa and *E. ortleppi* (G5) in Southern Africa [22].

Effective control of the disease is complex due to the number of intermediate hosts involved and includes public health education programs on the parasite cycle, host species involved and transmission pathways, especially in endemic rural and pastoral communities where livestock husbandry is the main source of livelihood is highly recommended [10, 23]. Reinforcement of veterinary surveillance, restricting home slaughter practices, and encouraging proper disposal of infected organs (burn or bury) to limit dog access, all supported by meat inspectors's training must be taken into consideration [10].

In Mozambique, reports on *Echinococcus* spp. either in dogs or in humans are limited [21]. Eggs of the Taeniidae family were isolated from domestic dogs in a southern district of Mozambique, however, the genus and/or species involved were not identified [24]. In humans, a seroprevalence of 14% for *E. granulosus* has been reported by Noormahomed et al. (2014), however, information on CE epidemiology and risk factors for CE is still unclear [25]. Thus, the aim of this study was to assess the knowledge, attitudes and perception of livestock farmers to CE and also to determine the prevalence of *E. granulosus* sensu lato in domestic dogs from southern districts of Mozambique.

Materials and methods

The study was conducted in southern districts of Mozambique and it combined interviews with dog owners, a coprological survey of dog endoparasites and molecular analysis of Taeniidae eggs (Fig. 1).

Interviewing of dog owners

We administered a total of 335 structured questionnaires (developed for this study, see Supplementary file 1) to dog owners in English and back-translated to the local language (*xi-changana*) or to Portuguese, depending on the language proficiency of the person being interviewed. The questionnaire assessed knowledge level, attitudes, and perceptions of dog owners regarding transmission, control, and prevention of CE. Questionnaires were administered by the principal investigator, who is a veterinary doctor (RDM) and a local technician who was trained to administer the questionnaire.

A pre-test study was conducted outside the study area to validate the questionnaire before the start of the study and included the local veterinary technician for each study location. The questionnaire consisted of three groups of questions; the first group was related to general demographic information of participants, the second consisted of information on community practices related to the risk of CE infections and the last set of questions focused on knowledge, attitudes and perceptions on CE. A photograph of a hydatid cyst in the liver and the lung was shown to participants to verify if they had ever seen or heard of such cyst(s) in organs of slaughtered livestock. Participants were selected for the study using a

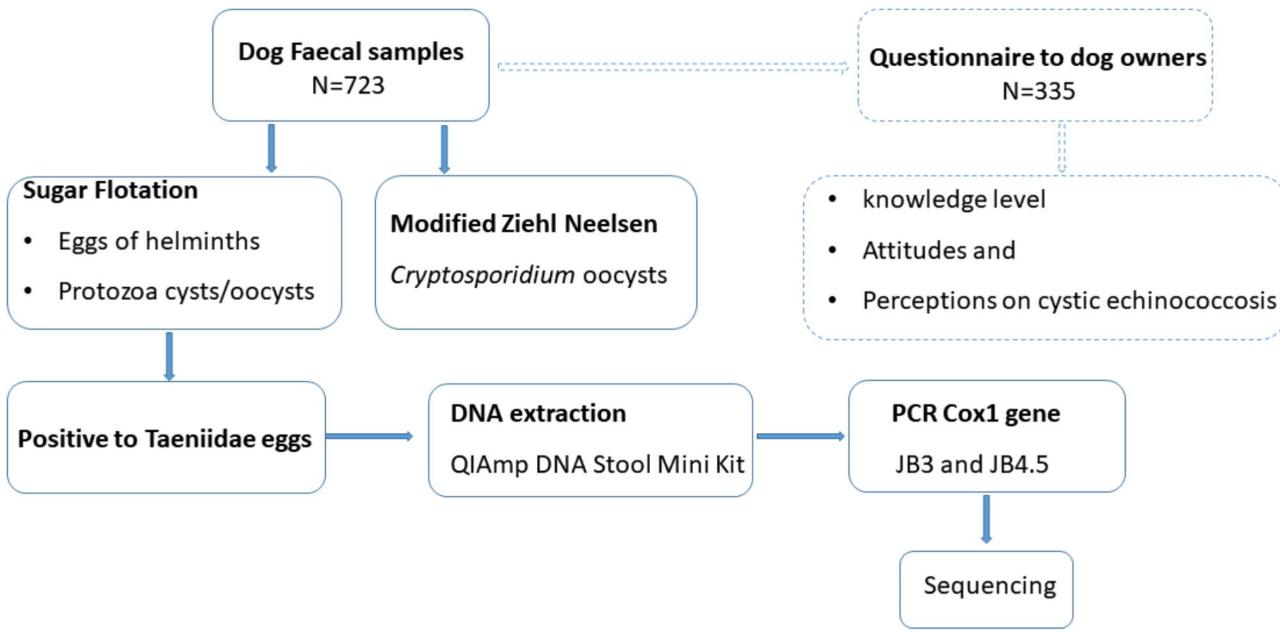

Fig. 1 Workflow chart of study participants (dogs and humans) representing the recruitment strategy, laboratory diagnostics and questionnaire contents

systematic random sampling after an oral consent form each participant confirming willingness and availability to participate in the study.

The following inclusion criteria were considered for a respondent to be eligible for the interview (i) being from a household with at least one dog, (ii) age of respondent above 18 years old, (iii) fecal sample(s) obtained from their dog(s) and (iv) having signed a consent form.

Coprological survey of endoparasites in dogs

This was to assess the prevalence of gastrointestinal parasites by using flotation solution and molecular methods were exclusively used to identify taeniid eggs isolated from fecal samples during flotation to species level (Fig. 1). Prior to the start of the study, a verbal consent was provided by dog owners to enable to access their dogs and to participate in the study. The study coincided with the anti-rabies vaccine campaign from December 2019 to November 2021 in selected communities of Limpopo National Park in the districts of Mapai, Chibuto and Massingire in Gaza province and in Mabote district, Inhambane province, located in the southern region of Mozambique (Fig. 2). The districts were conveniently selected based on the reported prevalence of 3.9% of *E. granulosus* by Miambo et al. (2022) in slaughtered cattle from the same study area [26].

Dogs were sampled from designated points during vaccination campaigns against rabies and in community residences of study district according to household's availability to handle their dogs. The sample size was determined with 95% of confidence level and 5% of precision level and estimated prevalence of 2.4% [27] using the following formula of [28]: $n = \frac{1.96^2 P\exp\,(1-P\exp)}{d^2}$ where Pexp is the expected prevalence; d the level of precision and n the required sample size. The sample size was adjusted (Naju) based on the district population size (N) of each district provided by the Ministry of Agriculture and the estimated sample size ($n = 384$), using the following formula: $Naju = \frac{N*n}{N+n}$. We obtained 388 samples from Massingire, 64 from Mapai, 109 in Mabote and 162 in Chibuto giving a total of 723 fecal samples which were collected from the rectum of dogs using latex gloves and identified with a unique number, location, age and sex. All samples were preserved in 70% ethanol and sent to the laboratory of parasitology, Faculty of Veterinary, Eduardo Mondlane University in Mozambique for further processing by copro-parasitological techniques using sugar flotation with specific gravity 1.27 for helminths eggs/oocysts/cysts isolation and by modified Ziehl-Neelsen staining for *Cryptosporidium* spp. oocysts identification [29].

Molecular analysis of taeniid eggs

All samples positive for taeniid eggs were sent to a laboratory for Molecular Biology, University of Sassari, Italy, for molecular analysis by PCR technique to identify the genus and/or species of the taeniid eggs.

DNA was extracted using the QIAmp DNA Stool Mini Kit (QIAGEN, Hilden, Germany) in accordance with the manufacturer's instructions. A fragment of approximately 391 bp coding for the partial cytochrome c oxidase 1 (Cox1) was amplified using the primers JB3 (5′-TTTTTGGGCATCCTGAGGTTTAT-3′) and JB4.5 (5’-A

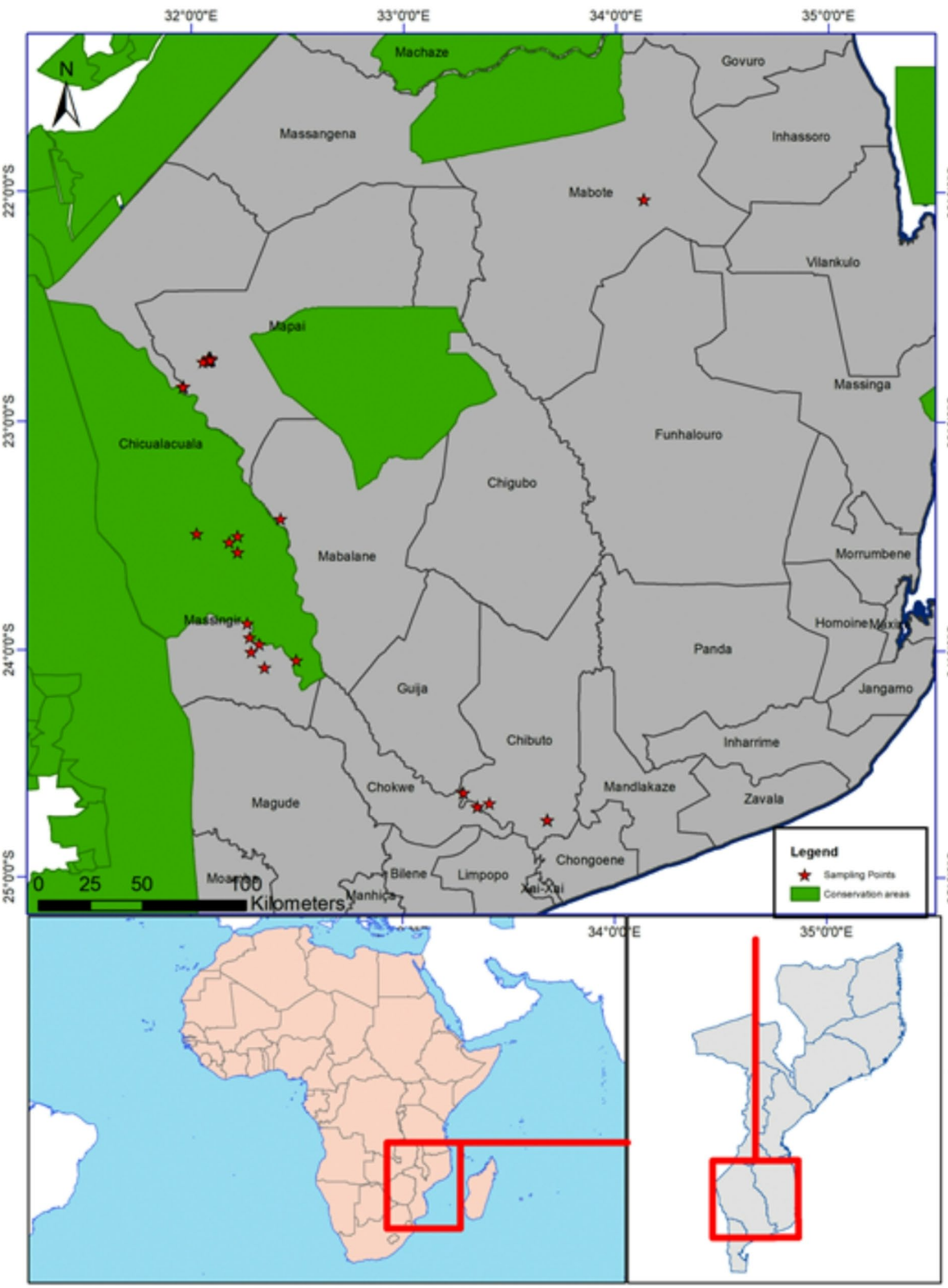

Fig. 2 Location of dog sampling and questionnaire points in districts (represented by red stars) of Massingire, Chibuto, Mapai and Mabote in southern Mozambique. Created by Fernando Chanisso Mulandane based on shapefiles moz_adm_20190607_shp from Mozambique - Sub-national Administrative Boundaries (https://data.humdata.org/dataset/cod-ab-moz?) and the World Database on Proteted Areas (WDPA) (https://www.protectedplanet.net/country/MOZ)

AAGAAAGAACATAATGAAAATG-3') according to Bowles et al. (1992) [30]. PCR reactions were carried in a final volume of 25 µl containing 10X PCR buffer, 1.5 mM $MgCl_2$, 0.2 mM of deoxynucleotide triphosphate (dNTPs), 0.2 µM of every primer and 1U of Thermus aquaticus DNA Polymerase (Thermo Fisher Scientific, Massachusetts USA) and 5 µl of genomic DNA. The thermal cycler conditions were 95 °C for 5 min, followed by 30 cycles at 94 °C for 30 s, 50 °C for 45 s, 72 °C for 35 s, and a final extension step at 72 °C for 10 min. PCR products were purified using Nucleospin Gel and PCR Clean Up (Macherey–Nagel GmbH & Co. KG, Duren, Germany) and sent for sequencing (Eurofins Genomics, Ebersberg, Germany).

Data analysis

Data were entered into Excel and exported to SPSS software version 20.0. For questionnaire data, descriptive statistics, and proportions at 95% confidence interval were applied and a p-values < 0.05 were considered statistically significant. Prevalence of parasites was determined based on the number of dogs infected by a specific egg/oocysts/cysts divided by the total number of examined dogs. Associations between frequencies of positivity for the detected parasites among sampling locations were determined using the chi-square or Fisher's exact test and a p-value < 0.05 was considered significant. Sequences were BLASTED in NCBI for identification with comparisons for similarity with sequences from GenBank.

Results

Demographic information

A total of 335 dog owners were interviewed and 85.4% (286/335) of participants being males, and 83.0% (278/335), aged between 26 and 45 years with a mean age of 34 years (Table 1). Agro-pastoralism was the dominant livelihood activity by the study communities with 61.6% (206/335), followed by pastoralism with 34.9% (117/335) (Table 1).

Community practices, dog care and general hygiene

Results from respondents on dog care and general hygiene practices are shown in Table 2. Most of the farmers owned livestock (76.7%; 257/335) and cattle were the main animal species raised by the community. Home slaughter of livestock especially of small ruminants was found to be a common practice (51%; 171/335) mostly during festive seasons.

Table 1 Demographic data of study questionnaire participants

Variable	Category	Frequency (%)	95% CI
Sex	Male	286(85.4)	81.5–89.0
	Female	49(14.6)	11.0-18.5
Age group	18–25	22(6.6)	4.2–9.5
	26–45	278(83.0)	78.8–86.9
	> 45	35(10.4)	7.5–13.7
Occupation	Student	12(3.6)	1.8–5.7
	Pastoralist	117(34.9)	29.9–40.0
	Agro-pastoralist	206(61.6)	56.1–66.9

Boy children were usually responsible for taking care of dogs (80.3%) and both boy and girl children were responsible for guiding cattle to grazing areas. The main purpose of dog ownership was to herd livestock (41.2%; 138/335) and hunt (27.2%; 91/335). Most dogs were allowed to roam freely (95.8%) defecating in the pasture area (66.6%). A smaller proportion of dogs were confined to roaming in the homestead yard (4.2%; 14/335). All participants of the study stated that their dogs had never been dewormed or treated even when sick due to the inability to pay for anthelminthic drugs and/or due to the lack of veterinary pharmacies in the districts of Mapai and Mabote. According to respondents, the only veterinary assistance given to dogs is the vaccination against rabies once a year when and if there was availability of vaccines offered freely by the government. Contact of dogs with wild animals was reported by participants from Mabote (69.7%; 76/109) and Chibuto (74.0%; 120/162) districts.

Home slaughtering of livestock was common (51.0%; 171/335) and the source of drinking water was untreated for all respondents. Washing fruits and vegetables before eating was practiced by 24.8% (83/335) and washing of hands by 33.1% (111/335) of the respondents.

Knowledge and perception on cystic echinococcosis

Respondents who knew or ever heard about zoonotic diseases transmitted by dogs were 50.8% (170/335); and of these, 67% (114/170) mentioned rabies, locally called "*mlungise*" (Fig. 3), and explained the transmission of the disease associating it with mortalities and witchcraft.

Knowledge of CE by district, sex and age in dog owners of southern districts of Mozambique is shown in Table 3. In total, 3% (10/335) of the respondents were aware of CE, however, when they were shown a photograph of a hydatid cyst 39.1% (134/335) of respondents confirmed to have observed such cysts in carcasses and organs, especially in goats but they did not know the causative agent. When asked about the location of observed cysts, they referred to the liver, lungs, muscles and intestines and the infected viscera/organs were usually fed to dogs 60.4% (81/134), buried 14.9% (20/134) or thrown away 24.6% (33/134) (Table 2).

Analysis of knowledge on CE according to demographic data (Table 3), showed that knowledge was higher in districts of Mabote and Chibuto (1.2%; 4/335), in males (2.7%; 9/335), in respondents aged between 26 and 45 years old and in agropastoralists (1.8%; 6/335) compared to other groups, however, none of the participants knew

Table 2 Responses on knowledge, practices, and attitudes towards cystic echinococcosis in Southern districts of Mozambique

Question	Response	Frequency (%)	95% CI
Person in charge of dog(s) care	Children	269(80.3)	76.1–84.5
	Women	32(9.6)	6.6–13.1
	Men	9(2.7)	0.9–4.8
	Children and Women	25(7.5)	4.8–10.4
Purpose of dog ownership	Guard	88(26.3)	21.5–31.0
	Hunt	91(27.2)	22.4–31.0
	Companionship	18(5.4)	3.3–7.8
	Shepherd	138(41.2)	35.8–46.9
Livestock ownership	Yes	257(76.7)	71.9–81.2
	No	78(23.3)	18.8–28.1
Home slaughter practice	Yes	171(51.0)	46.0-56.4
	No	164(49.0)	43.6–54.0
Cysts observed in viscera	Yes	134 (40)	34.4–44.2
	No	201(60)	55.8–66.6
How infected organs are disposed	Feed dogs	81(60.4)	52.2–68.7
	Throw away	33(24.6)	17.6–32.1
	Bury	20(14.9)	9.0-21.6
How are dogs kept	Roam free	321(95.8)	93.7–97.9
	Yard	14(4.2)	2.1–6.3
Where dogs defecate	Pasture area	246(73.4)	68.7–78.5
	Yard	32(9.6)	6.3–12.8
	Surrounding neighbors	57(17)	13.1–21.5
Dogs deworming	Yes	4(1.2)	0.3–2.4
	No	331(98.8)	97.6–99.7
Washing of fruits and vegetables before consumption	Yes	83(24.8)	19.7–29.9
	Sometimes	252(75.2)	69.9–80.0
Washing hands before eating	Yes	111(33.1)	28.7–38.5
	No	97(29)	24.2–34.3
	Sometimes	127(37.9)	32.5–43.0
Water treatment (boiling)	Yes	-	-
	No	335(100)	100
Contact of dogs with wild animals	Yes	198(59.1)	54.0-64.5
	No	137(40.9)	35.5–46.0

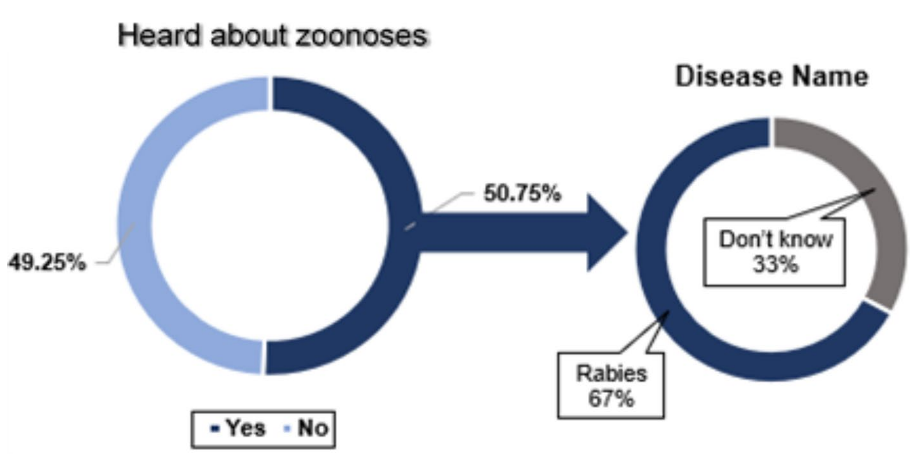

Fig. 3 Diagram showing respondents' knowledge on zoonotic diseases transmitted from dogs to humans in southern Mozambique with rabies as the only known disease

Table 3 Demographic characteristics of respondents on knowledge and perceptions of cystic echinococcosis in Southern districts of Mozambique

Variable	Category	Knowledge about cystic echinococcosis			
		Yes (%) (*n* = 10)	No (%) (*n* = 325)	OR, 95% CI	p-value
District	Mapai	2 (0.6)	62 (18.5)	0.038 (0.012–0.101)	0.841
	Mabote	4 (1.2)	105 (31.3)		
	Chibuto	4 (1.2)	158 (47.2)		
Gender	Female	1 (0.3)	48 (14.3)	0.028 (0.002–0.095)	0.747
	Male	9 (2.7)	277 (82.7)		
Age	18–25	0	22 (6.6)	0.070 (0.041–0.290)	0.116
	26–45	7 (2.1)	271 (80.9)		
	> 45	3 (0.9)	32 (9.6)		
Occupation	Student	1 (0.3)	11 (3.3)	0.065 (0.027–0.273)	0.432
	Pastoralist	3(0.9)	114 (34.0)		
	Agro-Pastoralist	6(1.8)	200 (59.7)		

Table 4 Prevalence of Gastrointestinal parasites of dogs in selected districts of Southern Mozambique (*N* = 723)

Parasites	**Mapai *N* = 64(%)**	**Mabote *N* = 109 (%)**	**Chibuto *N* = 162(%)**	**Massingire *N* = 388(%)**	**TOTAL *N* = 723 (%)**	***p*-value**
***Ancylostoma*spp**	25(39.1)	48(44.0)	80(49.4)	215(55.4)	368(50.9)	< 0.05
***Toxocara*spp**	2(3.1)	6(5.5)	9(5.6)	12(3.1)	29(4.0)	0.616
***Trichuris*spp**	3(4.7)	6(5.5)	4(2.5)	26(6.7)	39(5.4)	0.387
***Spirocerca*spp**	3(4.7)	11(10.1)	8(4.9)	33(8.5)	55(7.6)	0.419
Dipylidium caninum	4(6.3)	6(5.5)	2(1.2)	49(12.6)	61(8.4)	0.051
Taenidae eggs	2(3.1)	0	6(3.7)	9(2.3)	17(2.4)	0.09
***Isospora*spp**	6(9.4)	14(12.8)	6(3.7)	37(9.5)	63(8.7)	0.095
***Giardia*spp**	1(1.6)	0	8(4.9)	7(1.8)	16(2.2)	< 0.01
***Cryptosporidium*spp**	1(1.6)	0	3(1.9)	8(2.1)	12(1.7)	0.062
***Sarcocystis*spp**	6(9.4)	14(12.8)	6(3.7)	37(9.5)	63(8.7)	0.343

N = Sample size

about prevention and treatment of CE and differences were not significant.

Prevalence of Gastrointestinal parasites in dogs

The median age of the dogs was 2.6 years old, 39.4% (285/723) were under the age of 2 years, 60.6% (438/723) were above this age and the majority 61.5% (445/723) of the dogs were males. The prevalence of parasites identified according to each study district is summarized in Table 4. Overall, 94% (678/723) of the dogs were infected with at least one parasite. The prevalence of *Taenia* spp. was 2.4% (17/723) with high values reported in Chibuto (3.7%; 6/162) followed by Mapai (3.1%; 2/64) and Massingire (2.3%; 9/388) districts. Most of the taeniids (70.5%; 12/17) were observed from dogs ≥ 3 years old.

The overall prevalence of *Spirocerca* spp. was 7.6% (55/723), *Ancylostoma* spp. 50.9% (368/723), *Toxocara* spp. 4% (29/723), *Trichuris* spp 5.4% (39/723), *Sarcocystis* spp. 8.7% (63/723), *Dipylidium caninum* 8.4% (61/723), *Isospora* spp. 8.7% (63/723), *Giardia* spp. 2.2% (16/723) and *Cryptosporidium* spp. 1.7% (12/723). The prevalence of *Ancylostoma* and *Dipylidium* was significantly higher in the district of Massingire than in other districts ($p < 0.05$).

Molecular characterization of taeniid eggs

From 17 positive samples for *Taenia* spp. eggs, eight were amplified by PCR technique and BLAST analysis identified as *Taenia multiceps* (2) and *Taenia hydatigena* (6). Sequences were deposited in GeneBank with accession numbers PQ345436 - PQ345443. Isolates of *T. multiceps* showed a homology of 98.8% and 99.48% with previously published sequences of *T. multiceps* from China (KX547642.1 and MW228809.1) and homology of 99.7% to published sequences of *T. hydatigena* from Mongolia (AB792722.1) and Iran (MN478491.1).

Discussion

In the group of zoonotic diseases transmitted by dogs, our study showed that communities of southern districts of Mozambique were more aware of rabies compared to CE and other parasitic zoonotic diseases. *Echinococcus* and CE were unfamiliar to the respondents.

The importance given to rabies in the region can be associated with the severe symptoms of the disease. It is understood that infection in humans normally leads to death [31, 32]. Indeed, some of the survey participants stated that they had families and neighbors who had contracted the disease as confirmed by this statement by one of the respondents "*Our dogs are sometimes severely injured by wild dogs and mlungice cases always start when these dogs are hungry and approach to our communities attacking our herds.*"

Knowledge of CE from respondents from our study was comparable to the study by Khan et al. (2018) in Pakistan and we associate the lack of knowledge on the disease with limited veterinary services in the study districts, lack of awareness and apparent chronic nature of the disease and unknown burden associated with the disease related to low to none research interest on the parasite in animals and humans [21, 33]. The disease has been under-reported in Mozambique for more than fifty years in animals [21, 34] with only one serological study in humans [25]. In this study, HIV patients were tested and 7.3% were seropositive to *Toxocara* spp. and 17.3% to *Echinococcus* spp. in the province of Beira, Central region of Mozambique. In Sudan, the study of Wumbiya et al. (2017) reported a knowledge level of 41.9% [35], a value higher than that of our study.

Analysis of demographic factors showed higher knowledge levels within male participants compared to females, and in respondents aged between 26 and 45 years than in younger age groups. Our results differed from those reported by [36] where agropastoral and participants above the age of 36 were less knowledgeable of CE. In our study, knowledge may have been better in males because according to our study participants, males are responsible for livestock slaughtering having more chances to observe infected animals compared to female respondents. This might also have been influenced by the fact that most participants of the study (85.4%) were males.

Practices such as home slaughtering and feeding of dogs with infected offal by community members which are associated with low knowledge levels were predominant in the study area and might be contributing to dog infections and contamination of pastures with taeniids. Practices identified that may increase the risk of human infection were use of untreated water for drinking purposes, irregular washing of hands, and of fruits and vegetables before eating. Our results differed from the results by Khan et al. (2018) where good practices were implemented by 50% or more of the study participants [33]. Although in both studies, low knowledge level (3% and 4%) was reported. Children were mostly referred in our study to oversee dog care (80.3%) and this was significant. Since these dogs were not dewormed, kids might get infected at a younger age and symptoms only appear many years after and negatively affect their quality of life. Knowledge and perceptions of communities about CE was limited 3% (10/335).

Circulation of wild canids in pasture areas in communities of Mabote and Chibuto was reported and the potential of these hosts as reservoirs for the parasite must be taken into consideration [37]. Since we did not get positive dogs infected with *E. granulosus*, but positive livestock [21], we suspect the involvement of wild canids in the transmission of the parasite to livestock and potentially to humans. This is even real in communities within the National Park of Limpopo interface, which is a conservation area where different species of wild canids cohabit in the same environment with humans with the possibility of establishing a sylvatic cycle of *E. granulosus* in domestic environment.

Our results indicate that amongst dogs surveyed, 94% were infected by at least one parasite species.

The prevalence of 2.4% for taeniids in our study was higher than the value of 1.9% reported by Miambo et al. (2019) [24] in the same region of Mozambique and lower than the values of 19.67% reported in Nigeria [38], 23.87% in Ethiopia [39] and 73.2% in Tanzania [40]. There are other possible explanation for missing out on *E. granulosus* from the taeniid positive dogs or from this study. (i) The low CE prevalence in livestock as mentioned in the discussion could be associated with the findings of this study, few dogs positive for taeniid eggs, meaning limited transmission (ii) The methodology used, for mixed infection of *Taenia* and *Echinococcus* species, the single PCR is likely to pick out the dominant infection and therefore missing out the lesser infections. Nested PCR on individual eggs followed by RFLP or sequencing has the capability to detect mixed infections [41–43]. (iii) We cannot rule out the involvement of wild canids/felids in the transmission cycle, as shown recently in Namibia were all the 5 species/genotypes of *E. granulosus* sensu lato are well established in wildlife [44]. Our study adds more value in comparison to the previous studies conducted in Mozambique by the fact that the taeniids isolated were identified to species level. To our knowledge, this is the first study in Mozambique identifying taeniids from dog fecal samples using molecular tools. *Taenia multiceps* was detected in low frequency compared to *T. hydatigena*. The difference between the infection of *Taenia multiceps* and *T. hydatigena* in dogs could be associated with the mode of transmission, cysticerci of *T. hydatigena* are easily accessible compared to *T. multiceps* (location in the body), and generally in most studies the former is more common, although it might depend on the region [42]. Sheep and goats are common intermediate hosts for *T. multiceps* and *T. hydatigena* is responsible for negative impact on animal production and economic losses in poorly resourced farming [45, 46] whilst *T. multiceps* is of public health importance as a zoonosis with the parasite larvae being located in the brain, spinal cord and eyes, leading to neurological symptoms such as epileptic seizures, intracranial hypertension and hydrocephalus [47]. These results indicate that the dogs from our study area were fed raw organ meats, which was expected since they are raised alongside goats, sheep and cattle. A high prevalence of the parasite has been reported in goats in in the province of Tete in Mozambique [48]. The parasite causes a negative impact in animal production and economic losses. Additionally CE is among the 20 NTDs recognised by WHO for control and elimination and receives very little attention (including funding) compared to other NTDs controlled through chemotherapy such as soil-transmitted helminths, schistosomiasis, lymphatic filariasis and Trachoma [49].

To our surprise, we did not identify *E. granulosus* from taeniid eggs isolated from our study, since hydatid cysts were isolated from cattle and goats from the same region and this has been due the low number of dogs screened as the prevalence in dogs is usually low [26]. Improved results can also be achieved by freezing of faecal samples instead of preserving them in 70% ethanol which inhibits PCR or use of more sensitive methods such real-time PCR.

We associate the lack of research in zoonotic cestodes of dogs such as *E. granulosus* and other zoonotic parasites recorded in our study with the high cost of diagnosis by both molecular and immunological techniques [50]. Identification of Taeniidae species in dogs with emphasis on *E. granulosus* complex is of epidemiologic relevance in order to develop control measures using a One Health approach with collaborative efforts between human, animal and environmental health sectors to address the complex interaction of this parasitic infection essentially aimed to develop massive deworming of dogs, limiting the contamination of water and food sources by infected dog feces, as well the meat inspection in slaughterhouses and ultra sound-surveillance [13, 16].

For the isolation of adult *Echinococcus* spp from dogs, administration of purgatives has been reported to yield better results, however, this technique is laborious, with ethical concerns involved and risky to the handler requiring biosafety precautions [51, 52]. On the other hand, it is possible that dogs from our study were free from *E. granulosus* and that transmission cycles are being maintained by wild canids since there were reports of circulation of wild canids in the study communities.

Helminths of zoonotic potential, *Ancylostoma* spp. with a high prevalence rate (50.8%) followed by *Dipylidium caninum* (8.4%), *Trichuris* spp. (5.4%), *Toxocara* sp (4%), and protozoans *Giardia* spp (2.2%), *Cryptosporidium* (1.7%) and *Sarcocystis* spp (0.4%) were identified in our study. Similar results were reported from the previous study conducted by Miambo et al. (2019) [24] in southern district of Mozambique and in a study done in Gauteng province, South Africa [53]. The protozoan *G. intestinalis* and *Cryptosporidium spp.* which are of zoonotic potential and opportunistic in HIV patients, have been reported in Mozambique by [54, 55] from Maputo province and in HIV patients and in HIV-negative children all over the country [56–58] and molecular analysis of both parasites indicated that zoonotic and anthropic transmission cycles are important pathways of diarrhoea in Mozambique [59, 60] however, the role of domestic dogs in the transmission of this parasites is unknown due to lack of molecular studies in order to identify the parasite genotypes.

Limitation of study

Our study had some limitations that deserve to be highlighted. We only used one fecal sample, and it is possible that the frequency reported could be underestimated due to the intermittent shedding of eggs, also, the low sample size and low sensitivity of microscopic technique may have contributed to misdiagnosis of *Echinococcus.*

Conclusion

Knowledge of cystic echinococcosis in districts of southern Mozambique is low, hence, implementing awareness campaigns in the local communities is recommended through a One Health approach, considering control strategies which are already being implemented for the prevention and control of rabies.

Training communities to improve hygiene practices such as treatment of drinking water, and washing hands and vegetables before eating may reduce the risk of human infections. Home slaughter of livestock and feeding of dogs with infected offals is a common practice in the study communities and we recommend the provision of certified abattoirs and trained meat inspectors and collaboration of health and veterinary authorities in the dissemination of preventive measures for cystic echinococcosis and other zoonotic parasites transmitted from dogs.

Since there have been reports of *Echinococcus* infections in livestock from the same study area, where wild canids are common, there is a need for future epidemiological studies to investigate the potential source of infections for both wild and domestic animals using a large sample size of taeniid egg isolates, taking in account all the protocols for isolation and conservation of the parasite to avoid PCR inhibitors.

Supplementary Information

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Supplementary Material 1

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Author contributions
Conceptualization: RDM, SMSA, SM Methodology: RDM, SMSA, CT, AV, GD, SM Data analysis: RDM, SMSA, SMWriting: RDM, SMSA, SMFinal revision: RDM, SMSA, EVN, CT, AV, GD, CB, SWB, RTS, SM.

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Data availability
All data collected and analyzed during the study is included in this manuscript, and data can be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Dog sampling was approved by Regulatory Scientific Boards of Veterinary Faculty, Eduardo Mondlane University and permission to conduct study in districts was given by the Animal District Services. A written informed consent was signed by each participant after study objectives explanation and all data was treated confidentially according to the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Barnes AN, Davaasuren A, Baasandagva U, Gray GC. A systematic review of zoonotic enteric parasitic diseases among nomadic and pastoral people. PLoS ONE. 2017;12(11):e0188809.
2. Schweiger A, Ammann RW, Candinas D, Clavien P-A, Eckert J, Gottstein B, Halkic N, Muellhaupt B, Prinz BM, Reichen J. Human alveolar echinococcosis after Fox population increase, Switzerland. Emerg Infect Dis. 2007;13(6):878.
3. Nakao M, Lavikainen A, Iwaki T, Haukisalmi V, Konyaev S, Oku Y, Okamoto M, Ito A. Molecular phylogeny of the genus *Taenia* (Cestoda: Taeniidae): proposals for the resurrection of Hydatigera Lamarck, 1816 and the creation of a new genus Versteria. Int J Parasitol. 2013;43(6):427–37.
4. Deplazes P, Rinaldi L, Rojas CAA, Torgerson PR, Harandi MF, Romig T, Antolova D, Schurer JM, Lahmar S, Cringoli G. Global distribution of alveolar and cystic echinococcosis. Adv Parasitol. 2017;95:315–493.
5. Wu X, Fu Y, Yang D, Zhang R, Zheng W, Nie H, Xie Y, Yan N, Hao G, Gu X. Detailed transcriptome description of the neglected cestode *Taenia multiceps.* 2012.
6. Yamazawa E, Ohno M, Satomi K, Yoshida A, Miyakita Y, Takahashi M, Satomi N, Asanome T, Maeshima A, Shiotsuka M. First case of human neurocoenurosis caused by *Taenia serialis*: A case report. Int J Infect Dis. 2020;92:171–4.
7. Sapp SGH, Bradbury RS. The forgotten exotic tapeworms: a review of uncommon zoonotic Cyclophyllidea. Parasitology. 2020;147(5):533–58.
8. Gutema FD, Yohannes GW, Abdi RD, Abuna F, Ayana D, Waktole H, Amenu K, Hiko A, Agga GE. *Dipylidium Caninum* infection in dogs and humans in Bishoftu town. Ethiopia Dis. 2020;9(1):1.
9. Jansen F, Dorny P, Gabriël S, Dermauw V, Johansen MV, Trevisan C. The survival and dispersal of *Taenia* eggs in the environment: what are the implications for transmission? A systematic review. Parasites Vectors. 2021;14:1–16.
10. Craig PS, Hegglin D, Lightowlers MW, Torgerson PR, Wang Q. Echinococcosis: control and prevention. Adv Parasitol. 2017;96:55–158.
11. Thompson RCA. Biology and systematics of *Echinococcus*. Adv Parasitol. 2017;95:65–109.
12. Wen H, Vuitton L, Tuxun T, Li J, Vuitton DA, Zhang W, McManus DP. Echinococcosis: advances in the 21st century. Clin Microbiol Rev 2019, 32(2).
13. Thompson RCA. The molecular epidemiology of *Echinococcus i*nfections. Pathogens. 2020;9(6):453.
14. Budke CM, Deplazes P, Torgerson PR. Global socioeconomic impact of cystic echinococcosis. Emerg Infect Dis. 2006;12(2):296.
15. Battelli G. Echinococcosis: costs, losses and social consequences of a neglected zoonosis. Vet Res Commun. 2009;33:47–52.
16. Moro P, Schantz PM. Echinococcosis: a review. Int J Infect Dis. 2009;13(2):125–33.
17. Tamarozzi F, Deplazes P, Casulli A. Reinventing the wheel of *Echinococcus granulosus* sensu Lato transmission to humans. Trends Parasitol. 2020;36(5):427–34.
18. Romig T, Ebi D, Wassermann M. Taxonomy and molecular epidemiology of *Echinococcus granulosus s*ensu Lato. Vet Parasitol. 2015;213(3–4):76–84.
19. Magambo J, Njoroge E, Zeyhle E. Epidemiology and control of echinococcosis in sub-Saharan Africa. Parasitol Int. 2006;55(Suppl):S193–195.
20. Wahlers K, Menezes CN, Wong ML, Zeyhle E, Ahmed ME, Ocaido M, Stijnis C, Romig T, Kern P, Grobusch MP. Cystic echinococcosis in sub-Saharan Africa. Lancet Infect Dis. 2012;12(11):871–80.
21. Miambo RD, Afonso SMS, Noormahomed EV, Pondja A, Mukaratirwa S. Echinococcosis in humans and animals in Southern Africa development community countries: A systematic review. Food Waterborne Parasitol. 2020;20:e00087.
22. Ohiolei JA, Luka J, Zhu GQ, Yan HB, Li L, Magaji AA, Alvi MA, Wu YT, Li JQ, Fu BQ, et al. First molecular description, phylogeny and genetic variation of *Taenia hydatigena* from Nigerian sheep and goats based on three mitochondrial genes. Parasit Vectors. 2019;12(1):520.
23. Otero-Abad B, Torgerson PR. A systematic review of the epidemiology of echinococcosis in domestic and wild animals. PLoS Negl Trop Dis. 2013;7(6):e2249.
24. Miambo RD, Laitela B, Malatji MP, De Santana Afonso SM, Junior AP, Lindh J, Mukaratirwa S. Prevalence of *Giardia* and *Cryptosporidium* in young livestock and dogs in Magude district of Maputo Province, Mozambique. Onderstepoort J Vet Res. 2019;86(1):e1–6.
25. Noormahomed EV, Nhacupe N, Mascaró-Lazcano C, Mauaie MN, Buene T, Funzamo CA, Benson CA. A cross-sectional serological study of cysticercosis, schistosomiasis, toxocariasis and echinococcosis in HIV-1 infected people in Beira, Mozambique. PLoS Negl Trop Dis. 2014;8(9):e3121.
26. Miambo RD, Afonso SMS, Noormahomed EV, Malatji MP, Mukaratirwa S. Prevalence and molecular characterization of cystic hydatidosis in livestock slaughtered in Southern Mozambique. J Parasitic Dis. 2022;46(1):186–95.
27. Gomes AF. Intestinal parasitic infections of stray dogs from Huambo, Angola. 2000.
28. Thrusfield M. Chap. 17. Diagnostic testing. *Veterinary Epidemiology, Third Edition, Blackwell Science Ltd, Oxford* 2007:305–330.
29. Cheesbrough M. Medical laboratory manual for tropical countries, vol. 1: M. Cheesbrough, 14 Bevills Close, Doddington, Cambridgeshire, PE15 OTT.; 1981.

30. Bowles J, Blair D, McManus DP. Genetic variants within the genus Echinococcus identified by mitochondrial DNA sequencing. Mol Biochem Parasitol. 1992;54(2):165–73.
31. Grau-Pujol B, Massangaie M, Cano J, Maroto C, Ndeve A, Saute F, Muñoz J. Frequency and distribution of neglected tropical diseases in Mozambique: a systematic review. Infect Dis Poverty. 2019;8(1):103.
32. Adesina MA, Olufadewa II, OgaH YI, Nwachukwu N. Incidence and mortality from a neglected tropical disease (rabies) in 28 African countries. Folia Vet. 2020;64(2):46–51.
33. Khan A, Naz K, Ahmed H, Simsek S, Afzal MS, Haider W, Ahmad SS, Farrakh S, Wu W, Guan Y. Knowledge, attitudes and practices related to cystic echinococcosis endemicity in Pakistan. Infect Dis Poverty. 2018;7(01):79–93.
34. Grau-Pujol B, Massangaie M, Cano J, Maroto C, Ndeve A, Saute F, Muñoz J. Frequency and distribution of neglected tropical diseases in Mozambique: a systematic review. Infect Dis Poverty. 2019;8(06):1–11.
35. Wumbiya SD, Francis M, Wilfred E, Nasinyama GW, Eystein S, Adrian M, Munyeme M, Clare M, Daisy N, Bernadette M. Knowledge, attitude and practices towards cystic echinococcosis among pastoral communities in greater Kapoeta South Sudan. J Veterinary Med Res. 2017;4(5):9050–1086.
36. Omadang L, Chamai M, Othieno E, Okwi A, Inangolet FO, Ejobi F, Oba P, Ocaido M. Knowledge, attitudes and practices towards cystic echinococcosis in livestock among selected pastoral and agro-pastoral communities in Uganda. Trop Anim Health Prod. 2018;50:11–7.
37. Jenkins DJ, Morris B. *Echinococcus granulosus* in wildlife in and around the Kosciuszko National park, south-eastern Australia. Aust Vet J. 2003;81(1–2):81–5.
38. Ehimiyein AM, Maishanu DD, Ehimiyein IO. Prevalence of Gastrointestinal and haemo-parasites in hunting dogs in Zaria, Nigeria. Sokoto J Veterinary Sci. 2018;16(3):55–60.
39. Abere T, Bogale B, Melaku A. Gastrointestinal helminth parasites of pet and stray dogs as a potential risk for human health in Bahir Dar town, northwestern Ethiopia. Veterinary World 2013, 6(7).
40. Swai ES, Miran MB, Kasuku AA, Nzalawahe J. Taeniasis in non-descript dogs in Ngorongoro, Tanzania: prevalence and predisposing factors. Onderstepoort J Vet Res. 2016;83(1):1–6.
41. Hüttner M, Siefert L, Mackenstedt U, Romig T. A survey of *Echinococcus* species in wild carnivores and livestock in East Africa. Int J Parasitol. 2009;39(11):1269–76.
42. Mulinge E, Odongo D, Magambo J, Njenga SM, Zeyhle E, Mbae C, Kagendo D, Addy F, Ebi D, Wassermann M. Diversity of *Taenia* and *Hydatigera* (Cestoda: Taeniidae) in domestic dogs in Kenya. Parasitol Res. 2020;119:2863–75.
43. Muller SK, Assenga JA, Matemba LE, Misinzo G, Kazwala RR. Human leptospirosis in Tanzania: sequencing and phylogenetic analysis confirm that pathogenic *Leptospira* species circulate among agro-pastoralists living in Katavi-Rukwa ecosystem. BMC Infect Dis. 2016;16:273.
44. Aschenborn O, Aschenborn J, Beytell P, Wachter B, Melzheimer J, Dumendiak S, Rüffler B, Mackenstedt U, Kern P, Romig T. High species diversity of *Echinococcus* spp. In wild mammals of Namibia. Int J Parasitology: Parasites Wildl. 2023;21:134–42.
45. Varcasia A, Tamponi C, Ahmed F, Cappai MG, Porcu F, Mehmood N, Dessì G, Scala A. *Taenia multiceps* coenurosis: A review. Parasites Vectors. 2022;15(1):84.
46. Nzalawahe JS, Mlanzi DS, Lupindu AM, Ngowi H, Eisler MC. Household economic losses and community knowledge determine control strategies: A case of cerebral coenurosis in small ruminants in Northern Tanzania. 2023.
47. Lescano AG, Zunt J. Other cestodes: sparganosis, coenurosis and *Taenia crassiceps* cysticercosis. Handb Clin Neurol. 2013;114:335–45.
48. Afonso SMS, Mukaratirwa S, Hajovska K, Capece BPS, Cristofol C, Arboix M, Neves L. Prevalence and morphological characteristics of *Taenia multiceps* cysts (Coenurus cerebralis) from abattoir-slaughtered and experimentally infected goats. 2011.
49. World Health O. Accelerating work to overcome the global impact of neglected tropical diseases: a roadmap for implementation. In.: World Health Organization; 2012.
50. Siles-Lucas MM, Gottstein BB. Molecular tools for the diagnosis of cystic and alveolar echinococcosis. Tropical Med Int Health. 2001;6(6):463–75.
51. Lahmar S, Lahmar S, Boufana B, Bradshaw H, Craig PS. Screening for *Echinococcus granulosus* in dogs: comparison between Arecoline purgation, Copro-ELISA and CoproPCR with necropsy in pre-patent infections. Vet Parasitol. 2007;144(3–4):287–92.
52. Dakkak A, El Berbri I, Petavy AF, Boué F, Bouslikhane M, Fassi Fihri O, Welburn S, Ducrotoy MJ. *Echinococcus granulosus* infection in dogs in Sidi Kacem Province (North-West Morocco). Acta Trop. 2017;165:26–32.
53. Minnaar WN, Krecek RC. Helminths in dogs belonging to people in a resource-limited urban community in Gauteng, South Africa. Onderstepoort J Vet Res. 2001;68(2):111–7.
54. Banze L, Madureira AC, Zacarias BC, Nhacupe N, Mascaro-Lazcano C, Benson CA, Schooley RT, Noormahomed EV. Coinfection of HIV-1 with *Schistosoma* spp. And with intestinal parasites in patients attending Boane health center, Maputo Province, Mozambique. EC Microbiol. 2021;17(5):3–16.
55. Noormahomed EV, Tucuzo RM, Madureira AC. Prevalence of intestinal parasites among HIV infected and HIV uninfected patients treated at the 1º de Maio health centre in Maputo, Mozambique. EC Microbiol. 2017;9:231–40.
56. Ferreira FS, Pereira FLM. Martins MdRO: intestinal parasitic infections in children under five in the central hospital of Nampula, Northern Mozambique. J Infect Developing Ctries. 2020;14(05):532–9.
57. Bauhofer AFL, Cossa-Moiane ILC, Marques SDA, Guimarães ELAM, Munlela BA, Anapakala EM, Chiláule JJ, Cassocera M, Langa JS, Chissaque A. Intestinal protozoa in hospitalized under-five children with diarrhoea in Nampula–a cross-sectional analysis in a low-income setting in Northern Mozambique. BMC Infect Dis. 2021;21(1):1–8.
58. Nhambirre OL, Cossa-Moiane I, Bauhofer AFL, Chissaque A, Lobo ML, Matos O, de Deus N. Intestinal parasites in children up to 14 years old hospitalized with diarrhea in Mozambique, 2014–2019. Pathogens 2022, 11(3).
59. Messa A Jr, Köster PC, Garrine M, Nhampossa T, Massora S, Cossa A, Bassat Q, Kotloff K, Levine MM, Alonso PL. Molecular characterisation of *Cryptosporidium* spp. In Mozambican children younger than 5 years enrolled In a matched Case-Control study on the aetiology of diarrhoeal disease. Pathogens. 2021;10(4):452.
60. Muadica AS, Köster PC, Dashti A, Bailo B, Hernández-de-Mingo M, Balasegaram S, Carmena D. Molecular diversity of *Giardia duodenalis, Cryptosporidium* Sp.., and *Blastocystis* Sp. in symptomatic and asymptomatic schoolchildren in Zambézia Province (Mozambique). Pathogens. 2021;10(3):255.

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