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Insights to helminth infections in food and companion animals in Bangladesh: Occurrence and risk profiling

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A R T I C L E I N F O

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A B S T R A C T

Introduction: A better understanding of the epidemiology of helminths in animal hosts is important in order to ensure animal welfare, public health and food safety. The aim of this study was to explore parasitism in common animals in Bangladesh. Perception and understanding of animal owners regarding parasitic diseases management were also assessed.
Materials and methods: A total of 550 fecal samples were examined from common animals (cattle, goat, pig, chicken, dog, and cat) across three different areas of Bangladesh (Dhaka, Sylhet, and Chattogram) from January 2020 to March 2021. Associated risk factors were assessed through questionnaire surveys among 50 animal owners. Parasitological assessment was done using the combined sedimentation-flotation method, and factors associated with infection were modeled using mixed-effects logistic regression.
Results: Helminths including *Toxocara* sp., *Spirometra* sp., *Capillaria* sp., *Trichuris* sp., opisthorchiid, *Ascaris suum*, *Fasciola* sp., *Paramphistomum* sp., strongyles, hookworms, roundworms, taeniid, and acanthocephalans were detected in the examined animals, and overall prevalence was 59.3% (95% CI = 54.1–62.8). Parasites were found in 61.3% (245/400) of food animals and 54.0% (81/150) of companion animals. Animal owners have a good understanding of parasite infections; however, that knowledge was not being translated into practice. Logistic regression analysis showed that frequency of deworming, animal husbandry practice, contact with untreated animals, and treatment-seeking behaviors were significantly associated with parasitic infection.
Conclusion: Several types of zoonotic parasites are widely prevalent in animals of Bangladesh and pose a potential risk to human health. This study highlights the need to diagnose animal parasitic infection and intensified case management to avoid spillovers to animals and humans.

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1. Introduction

Livestock is one of the most promising sub-sectors of agriculture in Bangladesh and plays a critical role in the national economy of the country. Animals are raised for the purpose of food, recreation, religion, security, transportation, and income generation; they undoubtedly have lots of positive effects on civilization. It is estimated that livestock provides full-time employment for 20% of the total population and part-time employment for another 50% (Rahman et al., 2014). During Eid-ul-Adha, one of the largest religious festivals of Islam, over 10 million animals were sacrificed in the country. The majority of animals in Bangladesh is reared in household under extensive system, mostly free ranging. It is a common income generating source of unemployed women living in rural and slum areas. Although pig farming is not common, a good number of pigs are raised by several ethnic communities throughout the country. In addition, urbanization has increased the popularity of owning dogs and cats in recent years.

With the population growth, the interaction between humans, animals, and environment is increasing. Helminth infections are one the major threats to animal health, food safety and trade (Betson et al., 2020). These diseases are rarely associated with high mortality; however, various helminths described in animals are transmissible to humans (Battelli et al., 2006; Gordon et al., 2016). In Bangladesh, there is no data regarding the number of stray animals; free roaming animals (mostly dogs and cats) can be seen everywhere. In most cases, those animals get very little access to veterinary care. These animals have frequent contact with humans and other animals and might increase the transmission risk of a variety of zoonotic agents (Otranto et al., 2017). Also, asymptomatic animals are always neglected for parasitological examination, as they are commonly considered as parasite free. As a result, a large number of community peoples are unaware of this unseen risk to parasites (Engels and Zhou, 2020). This lack of attention along with the lack of public health surveillance put those animals at risk and exacerbates the risk of human spillover.

To design an effective parasite control program, monitoring parasites' managemental system, understanding various pathways and risk behaviors allow policymakers to develop control interventions (Battelli et al., 2006; Alarcon et al., 2014). Although data on regional prevalence is crucial to develop and implement control strategies, comprehensive information associated with parasitism of animals in Bangladesh is largely lacking. Also, little is known about how individuals and communities perceive parasitic diseases management. Therefore, this study aimed to give an overview of the occurrence of endoparasites among common animals and assess animal owners' perceptions and related practices. Findings from this study will be helpful for the quantification of the risks and developing recommendations on parasite management strategies in local communities.

2. Materials and methods

2.1. Study area, study population, and sample collection

A community based cross-sectional study carried out in January 2020 to March 2021 in three selected divisions of Bangladesh: Sylhet (ecological hilly zone; 24°54′23.77″N 91°50′50.29″E), Dhaka (ecological plain zone; 23°38′04.51″N 90°35′43.52″E) and Chattogram (ecological coastal zone; 22°46′28.51″N 91°34′24.54″E). Total 550 fecal samples from food animals (cattle: *Bos taurus*, goat: *Capra hircus*, pig: *Sus scrofa*), companion animals (dog: *Canis familiaris*, cat: *Felis catus*), and poultry (chicken: *Gallus domesticus*) were collected. Samples were collected from household and small-scale farms; medium and large-scale commercial farms were excluded from this study. Both domesticated and stray animals were included. The sample size was determined by the formula $N = (Z)^2P(1\text{-}P)/d^2$, where N = required sample size, Z = level of confidence (1.96), P = estimated prevalence (50%) and d = marginal error or absolute precision (5%). In this study, estimated prevalence was considered 50% since there were no reported studies in the study areas. Accordingly, more than 384 samples were needed; however, 550 animals were sampled and examined to increase precise of the mean. From Chattogram and Dhaka, 200 fecal samples were collected per geographical area (35 samples from cattle, goat, pig, chicken respectively, 40 samples from dog, 20 samples from cat). One hundred fifty samples were collected from Sylhet (30 samples from cattle, goat, pig, chicken respectively, 20 samples from dog, 10 samples from cat). Approximately 3–5 g feces were collected from each animal, placed in a fecal container, labeled, and fixed with 10% formalin. Fixed samples were transported to the Department of Parasitology, Chungbuk National University, Korea.

2.2. Laboratory methods

The specimens were checked for identification number and divided into two aliquots. One aliquot was used for the formol-ether concentration technique, while the other was kept for cross-checking. Parasitological assessment was done by modified formalin ether sedimentation method (Nath et al., 2021a) and sugar floatation techniques (Nath et al., 2021b). For modified formalin ether sedimentation technique, the procedure began with thorough mixing of fecal suspension and sieving through gauze into a test tube. The test tube was then vigorously shaken, followed by the addition of 3 ml ether as an extractor of fat and fecal debris. After centrifugation of 5 min at 1500 rpm, the supernatant discarded, and the sediment was examined using a light microscope. For sugar floatation technique, fecal sample was suspended in distilled water and sieved with a double layer of gauzes, transferred to test-tube, and centrifuged 1500 rpm for 5 mins. The supernatant was then poured off, and Sheather's sugar solution (appro. 1.27 specific gravity) was added as a flotation solution. The mixture was then vigorously shaken and centrifuged at 1000 rpm for another 10 mins. The tube was filled with the Sheather's sugar solution up to the upper meniscus and covered with a coverslip. About 15 mins later, the coverslip was removed, placed onto a glass slide, and examined under the microscope.The identification of eggs, ova, and larva was made based on standard keys such as size, shape, nature of the shell, and nature of germinal cells (Hendrix and Robinson, 2006).

2.3. Data collection, management, and analysis

The questionnaire survey was conducted among 50 animal owners, most of them rearing mixed type of animals. A purposive sampling technique was applied to draw the sample from the population. The inclusion criteria to participate in the study were the owner of local and non-industrial small livestock farmers. The questionnaire was specifically developed to assess knowledge, perceptions, and behaviors relating to animal management and parasitic diseases. For each correct response, a score of one “1” was given, and a zero “0” score was assigned to each wrong response. Here, we defined “extend of knowledge” as familiarity or comprehension of parasites, while “prevention practice” consisted of the steps taken to avoid parasitic infection or contamination. Knowledge was scored as high (≥13/18), medium (≥7–12/18), and low (<6/18). The Chi-square and Fisher's exact tests were used to analyze the association of all examined factors as independent categorical variables with the prevalence of each infection. The Chi-square and Fisher's exact tests were used to analyze the association of all examined factors as independent categorical variables with the presence or absence of infection. For risk measurements, odds ratio (OR) and 95% confidence interval (CI) were analyzed by a random effect logistic regression model logistic regression analysis. In all cases, *p*-value of less than 0.05 was taken as significant. Using STATA version 17 (StataCrop LP, Texas, USA) data analysis software, the statistics were performed (Lawrence, 2013).

3. Results

Overall, 59.3% (326/550 95% CI = 54.1–62.8) of examined animals tested was positive for one or more helminths. Among the host species, the overall infection index was 58.0% for cattle, 41.0% for goat, 79.0% for pig, 67.0% for poultry, 62.0% for dog and 38.0% for cat. Parasites were found in 61.3% (245/400) of food animals and 54.0% (81/150) of companion animals. Diverse types of helminth eggs were revealed during the parasitological assessment (Table 1, Fig. 1). Considering the copro-parasitological profiles, for cattle and goats, the most frequently observed parasites were strongyle-type eggs (67.2% 39/58 and 65.9% 27/41 respectively), whereas for the poultry, the most frequently observed parasites were roundworm (79.1% 53/67), and for pig, it was *Ascaris suum* (79.7% 68/79). For the dog, the most frequently observed parasites were *Toxocara canis* (64.5% 40/62), whereas for cats, that were hookworms (78.9% 15/19).

A total of 50 animal owners were included in this study, and complete response was obtained from all participants. Knowledge, and preventive practice of animal owners were presented in Table 2. On average, participants self-reported a good level of knowledge regarding general health (70.0%) and intestinal parasites (62.0%). Familiarity with deworming was consistent across the participants, 82.0% of participants mentioned that anthelmintic treatment is necessary. Only 16.0% of participants did health check-ups of their animals periodically. Only a few participants (6.0%) indicated that they would apply cleaning and disinfection measures around the

Table 1
Prevalence of intestinal helminth in animals.

Type of animals	Species	No examined	Number Positive		Tentative diagnosis	Size (μm) [$n = 10$]	Frequency/positive animals	
			n	%			n	%
Food animals	Cattle	100	58	58.0	Strongyle-type eggs	72–76 × 39–44.3	39	67.2
					Fasciola sp.	141–148 × 71–79	27	46.6
					Paramphistomum sp.	126–132 × 66–71	11	24.1
	Goat	100	41	41.0	Strongyle-type eggs	51–55 × 30–35	27	65.9
					Fasciola sp.	121–130 × 55–65	14	34.1
					Unidentified larvae	1.8–2.6 mm × 0.66–0.91 μm	5	12.2
	Pig	100	79	79.0	*Ascaris suum*	61–70 × 42–51	63	79.7
					Hookworm	69–78 × 44–49	35	44.3
					Trichuris sp.	50–64 × 28–36	18	22.8
					Acanthocephala	88–110 × 45–60	43	54.4
					Unidentified larvae	2.1–2.7 mm × 0.75–0.90 μm	7	8.9
	Chicken	100	67	67.0	Roundworms	69–78 × 44–49	53	79.1
					Capillaria sp.	44–48 × 24–28	32	47.8
					Unidentified larvae	1.6–2.3 mm × 0.58–0.82 μm	19	28.4
	Subtotal	400	245	61.3	–	–	–	–
Companion/stray animals	Dog	100	62	62.0	*Toxocara* sp.	65–80 × 60–70	40	64.5
					Trichuris sp.	58–66 × 29–37	29	46.8
					Hookworm	55–80 × 30–45	21	33.9
					Spirometra sp.	55–65 × 30–35	12	19.6
					Taeniid eggs	28–41 × 27–40	9	14.9
					Opisthorciid eggs	21–28 × 9–15	3	4.8
					Echinostome egg	105–120 × 60–76	1	1.6
	Cat	50	19	38.0	Hookworm	50–75 × 30–45	15	78.9
					Spirometra sp.	51–64 × 30–35	10	52.6
					Toxocara sp.	60–70 × 55–65	13	68.4
					Opisthorciid eggs	21–28 × 9–15	2	10.5
	Subtotal	150	81	54.0	–	–	–	–
Total		550	326	59.3	–	–	–	–

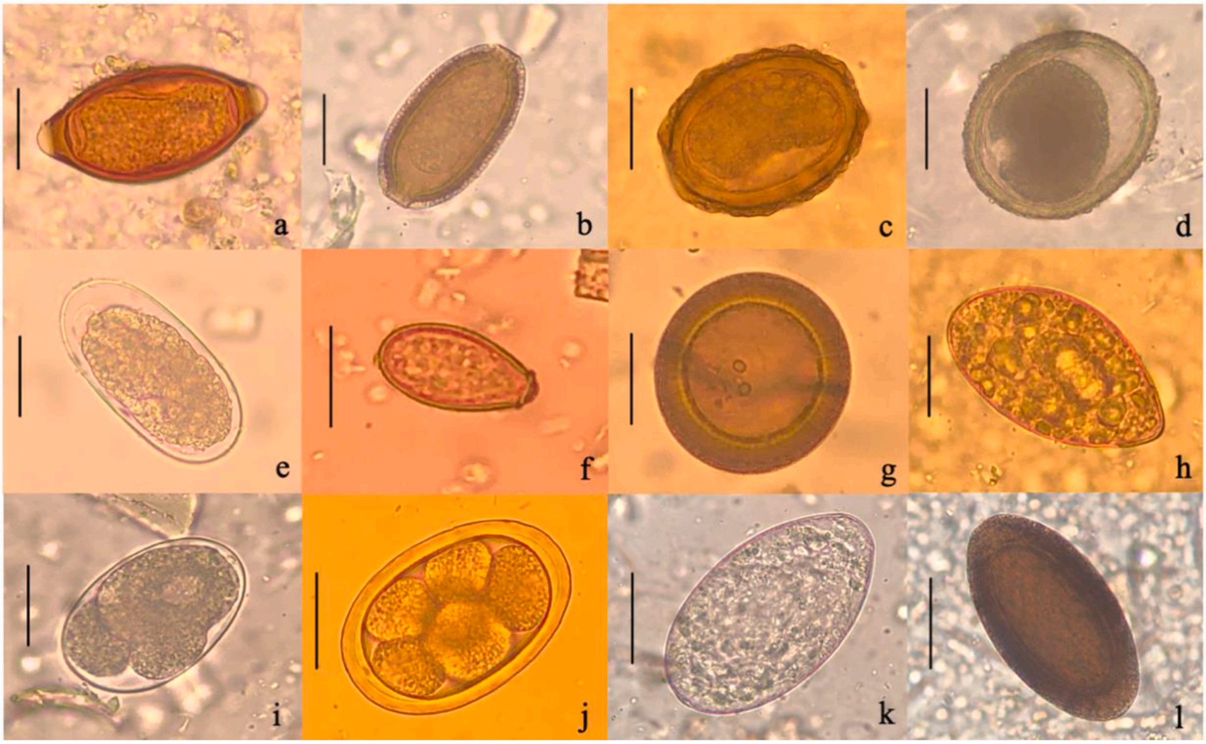

Fig. 1. Photomicrographs of observed helminth ova in animals: (a) *Trichuris* egg from pig, (b) *Capillaria* egg from chicken, (c) *Ascaris* egg from pig, (d) *Toxocara* egg from dog, (e) strongyle egg from goat, (f) opisthorciid egg from dog, (g) taeniid egg from dog, (h) *Spirometra* egg from cat, (i) hookworm egg from dog, (j*)* roundworm egg from chicken, (k) *Fasciola* egg from cattle, (l) acanthocephalan egg from pig (scale bar: 20 μm).

animal house as a response to infection prevention. The primary sources of treatment selected by a majority of farmers included non-vet stuff, including drug sellers intentionally or inadvertently.

The statistically significant factors were analyzed using a logistic regression model to assess their relative contribution to helminth infections prevalence and were presented in Table 3. The risk of helminth infections in animals was 1.61-fold higher for animals managed by irregular deworming and 5.21-fold higher for animals managed by non-vet persons. The risk of helminth infections was 3.42-fold higher in animals that had regular contact with other animals. Animals were less likely to be infected with reared by commercial feeds. Parasite infection in animals was more common in animals where owners do not perform rodent control and disinfectant in and around animal houses.

4. Discussion

Helminth infections in animals are likely much more common than is currently documented in Bangladesh. Here, infections with helminths are mostly asymptomatic, and infection was found in about two-thirds of the animals examined. The higher occurrence may be due to the unsafe animal husbandry practice, lack of veterinary attention, and the large number of stray animals, all of which contribute to the environmental contamination and the parasites transmission cycle (Chikweto et al., 2018). Mixed infection with more than one helminth was observed frequently in most cases. Free-range animals allow unregulated interaction between animals and humans and contribute to environmental contamination through fecal excretions, which are not usually removed or cleaned (Deplazes et al., 2011; Traub et al., 2005). The warm, moist climatic conditions of the country provide an ideal scenario for the development and transmission of parasites to hosts. Changes in the landscape due to urbanization, increased travel and global trade, presence of wet markets operating with poor hygiene, and absence of biosafety measures might also affect host-parasite interaction and play a role in disseminating parasites (Duscher et al., 2014). Most of the animals harbor parasites without visible clinical signs; however, those parasites can cause serious health damages in both humans and animals (Penakalapati et al., 2017). For example, animal hookworms can interfere with the productivity of animals by causing anaemia and hypoproteinemia; in humans, these species are causes cutaneous *larva migrans* or creeping eruption. Animal ascarids can cause visceral *larva migrans* in human (Beaver, 1958). Thus, community peoples need to be educated regarding risks of zoonoses, and the importance of regular parasite screening to avoid potential public health hazards.

Among those human infections acquired through contact with animals, it is believed that *larva migrans* caused by ascarids (*Toxocara canis*, *T. cati* and *Toxascaris leonina*), are most damaging and widespread (Ma et al., 2018). Ingestion of contaminated eggs with foods, and water, or raw liver of paratenic hosts the possible ways for humans to become infected (Ma et al., 2018; Fakhri et al., 2018;

Table 2
Knowledge, attitude and practice of animal owners ($n = 50$).

Variable	Response	Total n	Total %	χ^2	*P-value
Extend of knowledge					
General health	High	12	24.0	4.227	0.39
	Medium	23	46.0		
	Low	15	30.0		
	High	11	22.0		
Parasitic diseases	Medium	20	40.0	5.530	0.01
	Low	19	38.0		
	High	12	24.0		
Disposal of animal carcass	Medium	24	48.0	6.65	0.80
	Low	14	28.0		
	High	11	22.0		
Importance of regular deworming	Medium	34	68.0	9.201	0.01
	Low	5	10.0		
	High	7	14.0		
Parasite transmission	Medium	15	30.0	5.582	0.02
	Low	28	56.0		
Prevention practice					
Regular veterinary check-up at least one time every two months	Yes	8	16.0	43.671	0.01
	No	42	84.0		
Give animal anti-helminths drugs at least two times a year	Yes	29	58.0	3.641	0.61
	No	21	42.0		
	Always	3	6.0		
Disinfection in and around the animal shed/farm	Sometimes	11	22.0	14.71	0.00
	Never	36	72.0		
	Always	4	8.0		
Wearing boots while handling animals	Sometimes	12	24.0	7.221	0.03
	Never	38	76.0		
	Always	2	4.0		
Wearing gloves while handling animals	Sometimes	5	10.0	8.745	0.01
	Never	43	86.0		
	Always	3	6.0		
Using mask while handling animals	Sometimes	10	20.0	12.50	0.00
	Never	37	74.0		
	Always	11	22.0		
Isolating animals while sick	Sometimes	2	4.0	11.366	0.01
	Never	37	74.0		
	Doctors	5	10.0		
Primary measure when animals get sick	Drug seller	32	64.0	6.366	0.02
	Other farmers	2	4.0		
	Ownself	11	22.0		

* Statistically significant association at $P < 0.05$.

Table 3
Relationship of different variables with parasitic infection ($n = 31$).

Variable	Level	n = 31	%	Odd ratio	95% CI	*P-value
Frequency deworming	Irregular	18	58.1	1.61	0.63–3.32	0.10
	Regular	13	41.9	1.00		
Use commercial feed	No	22	70.9	2.43	1.35–4.49	0.02
	Yes	9	29.1	1.00		
Routine cleaning of animal house	No	19	61.3	2.17	0.47–5.22	0.04
	Yes	12	38.7	1.00		
Disinfection around the animal house	No	23	74.2	2.48	1.18–4.77	0.02
	Yes	8	25.8	1.00		
Primary measure while sickness	Non-vet	26	83.9	5.21	1.41–15.21	0.00
	Veterinarian	5	16.1	1.00		
Frequent contact with other animals	Yes	24	77.4	3.42	1.08–11.91	0.01
	No	7	22.6	1.00		

* Statistically significant association at $P < 0.05$.

Overgaauw and van Knapen, 2013). The majority of people infected with ascarids go unnoticed, but a small percentage acquire the severe or fatal disorders visceral *larva migrans*, ocular *larva migrans*, and covert toxocariasis (Ma et al., 2018; Bowman, 2020). Thus, the *Toxocara* infection in dogs and cats found high in this study could be a significant human health problem. In Bangladesh, no data related to human toxocariasis was found, and it is suggested that this should be a future avenue of investigation. Another highly prevalent ascarid nematode *Ascaris suum*, is responsible for significant economic losses in swine production, and its sister species, *Ascaris lumbricoides* infects human (Else et al., 2020). Ascariasis effects on cognitive development and contributes to chronic morbidity; particularly affects child growth via anorexia and malabsorption of nutrients abnormalities (Dold and Holland, 2011). The adult females *Ascaris* known to lay on average 200,000 eggs per day, increasing the chances of environmental contamination.

Nematodes belong to hookworms, and strongyles are among the major intestinal helminths of mammals, and some of them can infect humans (Utzinger et al., 2010; Loukas et al., 2016). Infection can occur either through ingestion or skin penetration of infective larvae. Behavior like open defecation practices, disposal of kids stools in environment, and indiscriminate use of animal manure contributes to its prevalence (Traub et al., 2005; Ngui et al., 2012). Trichuriasis (commonly known as whipworms) contributes to long-term nutritional morbidity and affects cognitive development, including dysentery syndrome and rectal prolapse (Mohd-Shaharuddin et al., 2019). Although animals' whipworm is closely related to human whipworm, the zoonotic importance of animals' whipworm as a cause of human disease is still controversial (Traversa, 2011); some human cases of visceral *larva migrans* by canid *Trichuris* species have been described (Areekul et al., 2010; Dunn et al., 2002; Marquez-Navarro et al., 2012). Another important nematode, *Capillaria* can be found parasitizing a wide number mammals and has cosmopolitan distribution (Camargo et al., 2010). Human capillariasis is a rare and neglected disease caused by several species of *Capillaria*. *C. hepatica* causes hepatic capillariasis, *C. philippinensis* produces intestinal capillariasis and *C. aerophile* (=*Eucoelus aerophili*) causes pulmonary capillariasis. Animals acquire infection by ingestion of embryonated eggs or *Capillaria* infected rodents, and human acquire infection through accidental ingestion infective stages with contaminated soil, vegetables and raw or poorly cooked fish (Wang et al., 2019).

Cestodes belonging to the genus *Spirometra* occasionally reported diverse host groups of mammals, including humans across the globe, including Bangladesh (Nath et al., 2021a; Jeon and Eom, 2019). Man gets infection through ingestion of infected cyclops or undercooked intermediate or paratenic host or by application contaminated tissues on skin as poultices. Cases of human sparganosis have been documented involving different organs like eye, brain and spinal cord, inguinal region, draining fluid of perinephric area (Jeon and Eom, 2019). Taeniid (*Echinococcus* spp. and *Taenia* spp.) affects millions of people and incurs significant economic costs, primarily in developing countries (Eom et al., 2020). Human taeniasis and echinococcosis are becoming most challenging issues in human and animal health across the world. However, these two genera of cestode cannot be differentiated based on egg morphology and size. Taeniid egg is extremely resistant, enabling them to withstand a wide range of environmental temperatures for many months (Eom et al., 2020; Thompson, 2017; McManus et al., 2003). The species has always been well recognized because of the enormous economic losses in the livestock industry. This study also observed high prevalence acanthocephalans (commonly known as thorny-headed worm) in swine fecal samples; a group of endoparasitic worms that lack a mouth and attach to hosts using a proboscis that covered with spiny hooks (Kamimura et al., 2018). *Macracanthorhynchus hirudinaceus* is a zoonotic acanthocephalan with cosmopolitan distribution occurs primarily in pigs and wild boars. These helminths rarely infect humans, who are occasional accidental hosts (Else et al., 2020; Migliore et al., 2021). Although acanthocephalans have been identified worldwide, they are poorly studied in Bangladesh.

The present study investigated the risk factors of parasitic infections of animals in Bangladesh. Several risk behaviors were observed in study areas that might have association with parasitic transmission. Animal parasitism was found associated with animal owners' treatment-seeking behaviors, husbandry practices, and frequent contact with other animals. Interviews with animal owners revealed that parasites are considered a cause of poor performance; however, their treatment is mostly based on available drugs without prior diagnosis. The benefits accruing from these salvage treatments were short-lived as treated animals returned to contaminated environments or other untreated animals and got reinfected quickly (Ellis-Iversen et al., 2010). Additionally, most animal owners did not take any veterinary advice, and their choice of drugs was based on the cheaper option or availability in the local pharmacies. Quality of the management and the degree of awareness is associated with daily activities, such as the careless handling of carcass, feces, or feed favor the transmission of parasites. Due to the behavior of coprophagia and geophagia, some animals are likely to ingest helminth eggs if feces are not regularly removed (Betson et al., 2020). In this study, animal owners were asked their first response if their animal became sick. Participants were the most likely to consult non-veterinarian staff as a first response treatment; major source of advice was from "drug seller" (locally called dealer) and non-veterinarian staffs (locally called quack). Almost all these dealers or quacks are unqualified, lack formal animal health training, and are largely responsible for antimicrobial resistance (inappropriate dosage with excessive antibiotics for quick recovery). In addition, in many cases, animals remain untreated, as owners fail to recognize disease or financial inability to spend for animals. Those untreated animals acts as reservoirs of parasites and continuously contributes to environmental contamination.

Going forward, several parasites of animals are known to cause diseases in humans, and it cannot be said with confidence that still others are not responsible for any diseases or pathological conditions. Even if certain parasites of animals are harmless to humans, they may be harmful to other animals. This study supports the argument that deworming cannot be the only method for controlling parasites if good husbandry practices are not applied (Utzinger et al., 2010). Integrated approaches including intensified case detection, treatment of infected animals, and regular monitoring need to be adopted to control strategies of parasitic diseases. Besides, awareness of animal owners and the public, appropriate communication strategies, and community engagement are necessary. The relationship between physicians, veterinarians, and the entire community should be reinforced to reduce the risk of public hazards as much as possible.

There are some limitations as our study. Due to the pandemic Covid-19 that occurred in the midst of our study and country-wise lockdown situation, we failed to obtain data from the wider community; thatmerely limits its generalizability. Moreover, there will be information bias, some classification was done based on the observations made by the interviewers. As the respondents could not properly answer some questions, some variables were omitted; there might have subjective variation in gathering data. Furthermore, we attempted to extract and amplify DNA from positive fecal samples, but we failed to achieve amplification. This was probably due to the fact that the specimens collected were fixed in formalin prior to transfer and subsequent long-term storage in 10% formalin.

5. Conclusion

This study presented a descriptive assessment of parasitic infection status of common animal species and almost two-third of the examined animals were found positive for helminthiases. A key message that emerges from this study is the under-reporting of animal parasitic diseases and, in many cases, insufficient attention paid to the diagnosis of these important sets of diseases since it usually goes unnoticed. Due to the high prevalence and diversity of parasites found in animals, these animals might play a crucial role in transmitting and maintaining parasites to other animals, humans, and the environment. Most of the animal owners over-reliance on anthelmintic to parasites controls rather than biosecurity-related practices. Integrated surveillance accompanying a test-and-treat campaign, improving animal husbandry practice, and educating owners should be among the priority recommendations and might be helpful to reduce the potential hazards of animal-borne parasitic diseases. The study findings will be helpful in articulating guidelines on control and elimination programs for helminthiases.

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Author contributions

All authors reviewed and provided feedback for this manuscript. The final version of this manuscript was vetted and approved by all authors.

Availability of data and materials

The datasets and biological materials used during the current study available from the first author and corresponding authors on reasonable request.

Declaration of Competing Interest

No potential conflict of interest has been declared by the authors.

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