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Gastro-intestinal nematodes in goats in Bangladesh: A large-scale epidemiological study on the prevalence and risk factors

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Goats greatly influence the economic sustainability of rural communities. However, parasitic diseases, especially gastrointestinal nematodes (GINs) are a major constraint on profitable small ruminants' production worldwide. During July- 2015 to June- 2016, we conducted a cross sectional study within seven topographic zones of Bangladesh to explore the level of infection and associated risk factors of GINs infections of goats. The study followed standard flotation and modified McMaster techniques. Among 1998 samples from goats; 1241 (62.1%) were found to be infected with one or more species of GINs by fecal examination for nematode eggs. The identified nematodes were strongyles (51.9%), *Strongyloides* sp. (19.0%) and *Trichuris* spp. (2.9%). By coproculture, we identified *Haemonchus* spp., *Oesophagostomum* spp., *Trichostrongylus* spp. and *Bunostomum* spp. in the different topographic zones. According to univariate analysis; young age, other breed than Black Bengal, animals in poor condition, backyard rearing system, muddy housing, illiterate farmers and rainy season were found significantly associated with GINs infections. Besides, other breed than Black Bengal, animals in poor condition, backyard rearing system, muddy housing and illiterate farmers were identified as the risk factors of GINs infections in goats. This is the first detailed epidemiological investigation of GINs of goats in Bangladesh. The epidemiological findings are expected to help formulate effective control strategies against GINs infections in goats by improving health status of animals, management system and education level of the farmers.

1. Introduction

Small ruminants, especially goats, are the integral part of the livestock sector, economy and the mainstay of livelihood of the majority of rural people in Bangladesh. In 2012, about 56% out of the world goats (1 billion) population were reared in Asia (FAO, 2015). Currently 25.61 million goats are being reared in Bangladesh. In the country, goats play an important role in poverty alleviation of resource-poor and privilege deprived people. However, GINs infections are still a major problem for efficient and profitable farming of goats worldwide (Claerebout et al., 2018). These parasites are particularly insidious and responsible for economic

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losses in the form of low productivity and increased mortality. Also, loss of appetite, stunted growth, cost of treatment and control strategies hinder the income targets in a great deal (Pedreira et al., 2006; Odoi et al., 2007; Chaudary et al., 2007). The economic loss due to parasitic infections has been estimated at millions of dollars per year in Australia, Sweden, the Netherlands, and Denmark (McLeod, 2004; Waller et al., 2001).

GINs in sheep and goats are prevalent worldwide from temperate to tropical zones (Choubisa and Jaroli, 2013; Zeryehun, 2012; Raza et al., 2014; Biffa et al., 2006). However, since they are geo-parasites, a favorable environment (adequate moisture and temperature) is necessary for the development and survival of their developmental stages (larvae). Larval development and survivability influence the transmission rate of the parasites and the clinical manifestations that differ from region to region. The geo-climatic conditions of Bangladesh are ideal for parasites and there have been demonstrated the existence of a wide range of GI nematodes in different regions of the country (Mondal et al., 2000; Rahman et al., 1996).

Many authors suggest setting an appropriate control strategy against parasitic infection in small ruminants in different regions around the world (Thamsborg et al., 1996; Vlassoff et al., 2001; Tinar et al., 2005). However, the design of control strategy varies significantly in different climatic and management systems. Therefore, to formulate an appropriate control strategy for GINs, it is important to identify specific risk factors that notably influence prevalence and severity of the clinical manifestation in Bangladesh. Until now, epidemiological studies conducted on GINs infections in goats in Bangladesh have been very limited and scattered (Nuruzzaman et al., 2012; Hassan et al., 2011), and the countrywide data on the GINs prevalence are not available. Moreover, the most important risk factors under different farming systems and geo-climatic condition are yet to be generated. Therefore, it is imperative to investigate the level/status and the associated risk factors of GINs infections of goats in Bangladesh.

2. Materials and methods

2.1. Ethics statement

While carrying out this research, no animals were harmed or unethically injured/killed. The authors tried to maintain highest possible ethical standards in their works. The study was approved by Animal welfare and ethical committee of Bangladesh Agricultural University (06/AWEC/2017).

Study design and area.

A cross sectional study was conducted to estimate the overall prevalence of GINs in goats in Bangladesh. Bangladesh lies in the north-eastern part of South Asia between latitudes 20°34′ N and 26° 38′N and between longitudes 88° 01′E and 92°41′E. Based on the soil topography, the country is divided into seven topographical zones, namely Madhupur tract, Barind tract, Tista silt, Brahmaputra Alluvium, Gangetic Alluvium, Coastal saline tract and Hill tract of Bangladesh (Fig. 1). In the study, we covered all the topographic zones and collected samples from Madhupur (Tangail district, Madhupur tract), Godagari (Rajshahi district, Barind tract), Badarganj (Rangpur district, Tista silt), Mymensingh Sadar (Mymensingh district, Brahmaputra Alluvium), Shailkopa (Jhenaidah district, Gangetic Alluvium), Char Fasson (Bhola district, Coastal saline tract) and Rangamati Sadar (Rangamati district, Hill tract). There is no distinct climatic difference among these seven zones. Generally, the climate of Bangladesh is subtropical monsoon characterized by wide seasonal variations in rainfall, high temperatures and humidity. In the country, three seasons can be distinguished; namely the cool-dry winter (November to February), the hot dry summer (March to June) and the hot-wet rainy season (July–October) (Ahmed et al., 1989). Samples were collected carefully by one sample collecting team in each of the three seasons, zone by zone; and we collected samples from each zone in each season by maintaining a sampling calendar.

2.2. Sampling strategy

A simple random sampling method was employed to study GINs infections in goats. The sample size was calculated to be 288 from each topographic zone of Bangladesh using the formula, $n = 1.96^2(Pexp\ (1 - Pexp))\ /\ d^2$, where n = sample size, P = expected prevalence, d = desired precision (Thrusfield, 1995). We used expected prevalence 75% (P= 0.75) as per the available literature, a precision of 5% (d = 0.05), and confidence level 95% (i.e. 1.96).

2.3. Study period

We carried out the study for one year, from July 2015 to June 2016

2.4. Questionnaire survey

A pretested and structured questionnaire with information of the host, the farm management system and farmers were administered with the participants. Data were collected by examining the animals and by interviewing the owners of the animals. The questions and responses were recorded for statistical analysis. The variables included age, sex, breed, physiological condition of male and female, body condition of the animals (e.g.; BCS), the rearing system, flock size, housing, use of anthelmintic, socio-economic status, knowledge about GINs and education level of farmers, and seasons.

Data associated with some of the aforementioned variables were recorded by examining the animals. Age of the animal was categorized into three groups:1–6 months, ˃6–18 months and >18 months following eruption chart of teeth and also by interviewing the farmers (Samad, 2008). The physiological condition of females was categorized as pregnant, lactating and

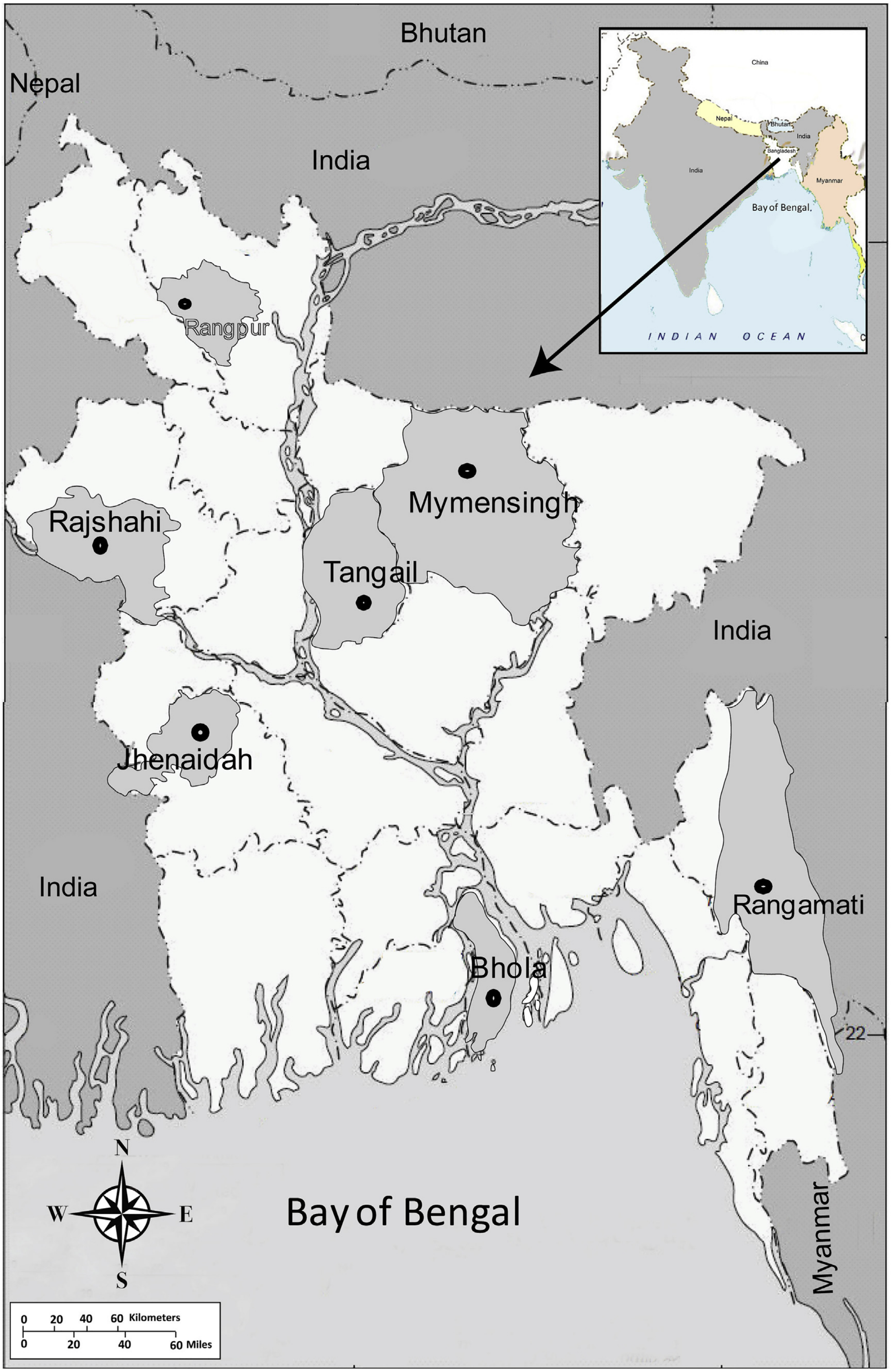

Fig. 1. Seven topographic zones of Bangladesh from where samples were collected from goats.

non-pregnant. The physiological condition of males was grouped into non-breeding and breeding male. Breed of goats were categorized into Black Bengal goat and other than Black Bengal goats. Body condition was categorized as animals in poor condition (BCS ≤ 2) and good condition (BCS $>$2) following the parameters described Villaquiran et al. (Villaquiran et al., 2005). Briefly, in the case of BCS ≤ 2, animals were considered emaciated and weak. The backbone was visible with continuous ridge and the flank was hollow. Ribs could be seen or covered with small amount of fat. The intercostal spaces were smooth but could be penetrated. In BCS $>$2, animals were considered apparently healthy. The backbone was not prominent or could not be seen or found covered with layer of fat. The intercostal space could be felt by pressure or found cover with excessive fat. The management system was recorded by visiting the farms and farmers' houses. The rearing system of animals was categorized as backyard and semi-intensive; flock size was grouped as ≤5, 6–20 and $>$20 and housing was categorized as muddy and concrete/slatted. The farmers' information was recorded by interviewing the owners of the animals.

2.5. Collection of samples and microscopic examination

Fresh fecal samples were collected directly from the rectum. About 3–5 pellets for standard flotation technique and two grams for McMaster technique were kept with few drops of 10% formalin in separate suitable airtight screw cap vials. In the laboratory, fecal samples were examined for the detection of nematode eggs employing standard procedures of flotation using saturated sodium chloride (NaCl) as flotation fluid (Taylor et al., 2007). Briefly, 3–5 pellets of fecal sample were thoroughly mixed with 10 ml of flotation fluid and poured into a test tube. More flotation solution was added into the suspension to fill the top of the tube. A coverslip was placed on the top of the surface and left for 10–15 min. Then, the coverslip was removed and examined under microscope. Identification of nematode eggs such as strongyles, *Strongyloides* sp. and *Trichuris* spp. were done following keys and description given by Soulsby (Soulsby, 1982) and Thienpont et al., (Thienpont et al., 1986). This qualitative technique was followed by the quantitative approach named as modified McMaster egg counting technique (Zajac and Conboy, 2012). In the process, positive samples were subjected to EPG counting to determine the number of eggs per gram of feces. Briefly, two grams of fecal pellet was gradually mixed with 28 ml flotation solution (saturated salt solution, specific gravity 1.200). The suspension was thoroughly stirred and allowed to pass through a sieve to remove coarse particles. The chambers of McMaster slide were filled with the suspension and allowed to stand for 5 min to float all parasitic eggs. Then, the slide was examined under microscope using low power objective (10×) and counted all eggs inside of the grid areas in both chambers.

According to Taylor et al. (Taylor et al., 2007), egg counts from 50 to 500, $>$500–1000 and $>$1000 per gram of feces are considered as light, moderate and heavy infection, respectively (Taylor et al., 2007). Furthermore, for the identification of strongyles, pooled fecal samples from each zone were considered for culture. Fecal cultures were prepared by incubating pooled feces at 26–28 °C for 7 days at 80% humidity. After which, harvesting the third stage larvae and identification of the most important nematode genera were performed in goats according to Van Wyk and Mayhew (Van Wyk and Mayhew, 2013).

2.6. Statistical analyses

The data were processed using computer program, SPSS 20.0, for statistical analysis to estimate the strength and statistical significance of the associations between predictor variables and GI nematodes infection. At first, data were organized for univariate analysis to find out the effect of individual risk factors on GINs infection. The variables that resulted significant ($p < 0.05$) in the univariate analysis were selected as potential candidates for multivariable analysis (multiple logistic regression with backward stepwise elimination). The p values for data inclusion and exclusion were set at 0.05 and 0.1, respectively. The final model was constructed with a significance level of $p<0.05$. Kruskal Wallis test was used to compare the mean EPG value of fecal egg count.

3. Results

3.1. More than half of the investigated goats were infected with GINs

In the study, a total of 1998 fecal samples of goats were collected and examined to know the overall prevalence and intensity of infection for GINs in different topographic zones of Bangladesh. Among the examined samples, 1241 were found to be infected with one or more GINs. The overall prevalence of GINs was 62.1% and the intensity of infection was 347.3 ± 11.6. The spatial distributions of prevalence and intensity of infection ranged from 46.2% to 76.3% and 141.9 ± 5.8 to 451.2 ± 31.4 respectively, and the significant variation was found among the topographic zones (Table 1).

The identified eggs from the fecal samples were strongyles (51.9%), *Strongyloides* sp. (19.0%) and *Trichuris* spp. (2.9%). Indistinguishable eggs were classed as strongyles (Table 2). To confirm species of strongyles, coproculture from pooled samples were performed, and *Haemonchus* spp., *Oesophagostomum* spp., *Trichostrongylus* spp. and *Bunostomum* spp. were identified by the detection of larvae. While considered the proportion of the parasitic larvae, *Haemonchus* spp. was found at the highest proportion in all the regions of this study, although its relative frequency varied from region to region (50–70%). *Oesophagostomum* spp. was the second highest in all the regions (15–29%) except Bhola (3%). However, relative frequency of *Trichostrongylus* spp. (4–18%) and *Bunostomum* spp. (4–12%) were very low compared to the parasitic larvae investigated in the different regions (Fig. 2).

The intensity of infection among 1241 positive samples indicated that most of the animals were lightly infected (84.27%) followed by moderate (10.9%) and heavy (4.8%) infection (Table 3).

Table 1
Prevalence and intensity of GI nematodes infection of goats in different topographic areas of Bangladesh.

Regions	Infected (examined)	Prevalence (%)	EPG	
			Range	Mean ± SE
Bhola	171 (297)	57.6[a]	50–4100	397.1[a] ± 45.5
Rangpur	213 (279)	76.3[b]	50–2750	403.1[b] ± 26.0
Rangamati	183 (286)	64.0[a]	50–5100	466.4[c] ± 43.2
Jhenaidah	164 (226)	72.6[b]	50–2300	451.2[d] ± 31.4
Mymensingh	208 (337)	61.7[a]	50–1350	287.8[e] ± 31.1
Tangail	156 (338)	46.2[c]	50–500	141.9[f] ± 5.8
Rajshahi	146 (235)	62.1[a]	50–1100	243.5[g] ± 17.8
Overall	**1241 (1998)**	**62.1**	**50–5100**	**347.3 ± 11.6**

Values with different letters within a column differ significantly ($p<0.05$); EPG, Egg Per Gram.

Table 2
Prevalence of identified GI nematodes of goats in Bangladesh.

Name of parasites	Infected	Prevalence (%)	95% CI of prevalence
Strongyles	1036	51.9	49.7–54.0
Haemonchus spp.			
Oesophagostomum spp.			
Trichostrongylus spp.			
Bunostomum spp.			
Strongyloides sp.	380	19.0	17.3–20.7
Trichuris spp.	57	2.9	2.1–3.6
Total (N = 1998)	**1241**[a]	**62.1**	**60.0-64.2**

[a] Total no. of animals affected is less than the summation of individual infection because same animal was infected with more than one type of gastro-intestinal parasites; N, total number of samples collected; CI, confidence Interval.

3.2. Association of different biotic and abiotic factors with GINs

The study was also planned to identify the significance of association between different biotic and abiotic factors with GINs infection in goats by univariate analysis. The results related to host factors revealed that young age, other breed than Black Bengal and animals in poor condition were significantly associated with the GINs infection. EPG were also counted which ranged from 50 to 5100. In host factors, higher intensity was found in the young (1–6 months and >6–18 months), other than Black Bengal, stressed females (pregnant and lactating) and animals in poor condition (Table 4). In the farm management system, farming and housing system were significantly associated with GINs infection. Coprological examination revealed that comparatively higher infection was found in backyard rearing, small flock sizes and muddy housing system than that in semi-intensive system, organized farms, large flock size and concrete/slatted housing system. No significant variation was found between anthelmintic used (56.9%) and unused groups (62.5%) (Table 5).

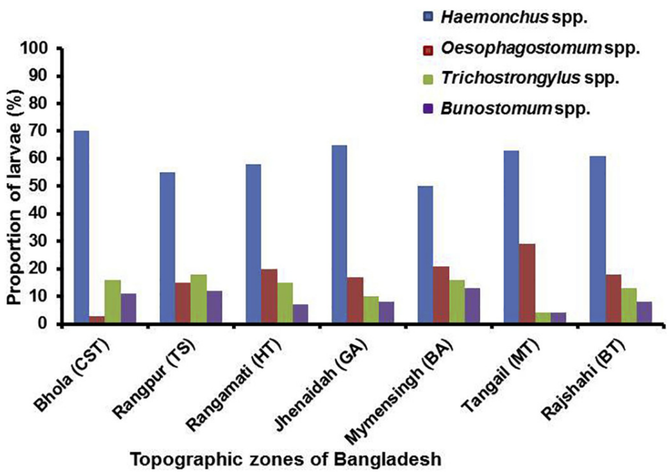

Fig. 2. Proportion of larvae in pooled fecal samples from goats in seven topographic zones of Bangladesh. Abbreviation: CST, Coastal Saline tract; TS, Tista silt; HT, Hill tract; GA, Gangetic Alluvium; BA, Brahmaputra Alluvium; MT, Madhupur tract; BT, Barind tract.

Table 3
Degree of infection based on EPG count of examined positive samples for nematode parasite.

Intensity of infection	EPG	Frequency (%)
Light	50–500	1045 (84.2)
Moderate	>500–1000	136 (10.9)
Heavy	>1000	60 (4.8)

Table 4
Univariate analysis of potential risk factors in relation to host for GI nematodes in goats.

Risk factor		Infected/examined	Prevalence (%) (95% CI)	OR (95% CI)	EPG
					Mean ± SE
Sex	Female	796/1263	63.0^{a} (60.4–65.7)	1.11 (0.9–1.3)	358.9^{a} ± 15.7
	Male	445/735	60. 5^{a} (57.0–64.1)		326.6^{a} ± 16.2
Age	1-6 months	156/253	61.7^{a,b} (55.7–67.7)	1.06 (0.8–1.4)	447.4^{a} ± 43.9
	>6–18 months	459/705	65.1^{b} (61.6–68.6)	1.22 (1.0–1.4)	340.9^{b} ± 16.5
	>18 months	626/1040	60. 2^{a} (57.2–63.2)		326.9^{c} ± 16.2
Breed	Other than Black Bengal goats	217/322	67.4^{a} (62.3–72.5)	1.31 (1.0–1.7)	347.6^{a} ± 13.2
	Black Bengal goat	1024/1676	61.1^{b} (58.8–63.4)		345.2^{a} ± 23.9
Physiological condition of female	Pregnant	133/200	66.5^{a} (60.0–73.0)	1.30 (0.9–1.8)	402.3^{a} ± 34.3
	Lactating	253/384	65.9^{a} (61.1–70.6)	1.26 (0.9–1.6)	360.5^{b} ± 22.3
	Non pregnant	410/679	60.4^{a} (56.7–64.1)		333.3^{c} ± 28.4
Physiological condition of male	Non breeding	348/567	61.4^{a} (57.4–65.4)	1.16 (0.8–1.6)	358.8^{a} ± 37.3
	Breeding	97/168	57.7^{a} (50.3–65.2)		317.7^{a} ± 17.9
Body condition	Animals in poor condition	753/1081	69.7^{a} (66.9–72.4)	2.01 (1.6–2.4)	354.2^{a} ± 14.5
	Animals in good condition	488/917	53.2^{b} (50.0–56.4)		336.6^{b} ± 19.4

Values with different letters within a column in each variable differ significantly ($p<0.05$); EPG, egg per gram; OR, odds ratio; CI, confidence interval.

The questionnaire survey revealed the education level of farmers which was strongly associated ($p = 0.004$) with GINs infection in goats. EPG were also lower in those animals reared by the farmers with higher economic status, having knowledge about GI nematodes, and literate farmers (Table 6). The highest prevalence and mean EPG of GINs were observed in the rainy season (65.5%, 397.9 ± 26.0) followed by summer (61.4%, 327.7 ± 18.6) and winter (58.7%, 327.6 ± 16.3) (Table 7).

3.3. Potential risk factors of GINs infection in goats

To identify risk factors, the final logistic regression model was employed. In this analysis, seven variables with $p < 0.05$ in univariate analysis were selected to fit in this model. The final logistic regression model showed that other breed than Black Bengal, animals in poor condition, backyard rearing system, muddy housing and illiterate farmers had strong association with GINs infection (Table 8). The risk of GINs infection in goat was 2.06-fold higher among the animals in poor condition ($p = 0.000$) compared with the animals in good condition. The risk was also higher in other than the Black Bengal goats ($p = 0.000$), backyard rearing ($p=0.000$), muddy housing ($p=0.001$) and illiterate farmers ($p=0.01$) than that of the Black Bengal goats, semi- intensive systems, concrete or slatted housing and literate farmers, respectively.

Table 5
Univariate analysis of potential risk factors in relation to farm management for GI nematodes in goats.

Risk factor		Infected/examined	Prevalence (%)	OR (95% CI)	EPG
					Mean ± SE
Rearing system	Backyard	1107/1732	63.9^{a} (61.7–66.2)	1.74 (1.34–2.26)	348.7^{a} ± 12.6
	Semi- intensive	134/266	50.4^{b} (44.4–56.4)		335.5^{a} ± 28.9
Flock size	≤5	1057/1688	62.6^{a} (60.3–64.9)	1.13 (0.75–1.6)	333.9^{a} ± 46.8
	6–20	122/206	59.2^{a} (52.5–65.9)	0.98 (0.6–1.5)	345.6^{a} ± 12.2
	>20	62/104	59.6^{a} (50.2–69.0)		368.9^{a} ± 47.9
Housing	Muddy	1085/1722	63.0^{a} (60.7–65.3)	1.31 (1.01–1.6)	349.7^{a} ± 12.8
	Concrete or slatted	156/276	56.5^{b} (50.7–62.4)		346.9^{a} ± 26.0
Use of anthelmintic	No	1154/1845	62.5^{a} (60.3–64.8)	1.26 (0.91–1.7)	369.5^{a} ± 33.9
	Yes	87/153	56.9^{a} (49.0–64.7)		345.6^{a} ± 12.2

Values with different letters within a column in each variable differ significantly ($p<0.05$); EPG EPG, egg per gram; OR, odds ratio; CI, confidence interval.

Table 6
Univariate analysis of potential risk factors in relation to farmer for GI nematodes in goats.

Risk Factor		Infected/examined	Prevalence (%) (95% CI)	OR (95% CI)	EPG
					Mean ± SE
Socio-economic status	Poor	870/1379	63.1[a] (60.5–65.6)	1.32 (0.85–2.1)	363.9[a] ± 15.1
	Medium	322/532	60.5[a] (56.4–64.7)	1.18 (0.75–1.8)	332.7[a] ± 38.5
	Rich	49/87	56.3[a] (45.9–66.7)		304.7[a] ± 17.7
Knowledge about GI nematodes	No	1164/1866	62.4[a] (60.2–64.6)	1.18 (0.82–1.6)	349.7[a] ± 12.3
	Yes	77/132	58.3[a] (49.9–66.7)		311.7[a] ± 27.1
Education level	Illiterate	1044/1642	63.6[a] (61.3–65.9)	1.40 (1.1–1.7)	356.1[a] ± 13.3
	Literate	197/356	55.3[b] (50.2–60.5)		300.5[a] ± 19.2

Values with different letters within a column in each variable differ significantly ($p < 0.05$); EPG EPG, egg per gram; OR, odds ratio; CI, confidence interval.

Table 7
Univariate analysis of seasons as the potential risk factors for GI nematodes in goats.

Risk Factor		Infected/examined	Prevalence (%) (95% CI)	OR (95% CI)	EPG
					Mean ± SE
Seasons	Rainy	488/745	65.5[a] (62.1–68.9)	1.33 (1.1–1.6)	397.9[a] ± 26.0
	Summer	405/660	61.4[ab] (57.6–65.1)	1.12 (1.0–1.4)	327.7[b] ± 18.6
	Winter	348/593	58.7[b] (54.7–62.6)		327.6[b] ± 16.3

Values with different letters within a column in each variable differ significantly ($p < 0.05$); EPG, egg per gram; OR, odds ratio; CI, confidence interval.

4. Discussion

GINs have great economic impact in goat rearing particularly in areas where the bloodsucking nematode, *H. contortus* is the predominant species (Zajac, 2006). Hence, we estimated the prevalence of GINs in goats along with the analysis of risk factors associated with the infection.

Our study revealed that all the investigated topographic zones had a high prevalence rate along with varying degrees of infection (46.2% to 76.3%; 141.9 ± 5.8 to 466.4 ± 43.2). However, prevalence and intensity of the infection of GINs was very low in Tangail. Low prevalence and intensity might be associated with the feed used for goats in this region. Almost all the samples in this study area were collected from backyard animals. The animals frequently consumed pineapple and papaya leaves which contain ananain and papain, respectively. Anthelmintic activity of ananain and papain has been reported and shown to reduce parasitic infection (Behnke et al., 2008). The overall prevalence of GINs estimated in the present study was 62.1%. The observed prevalence was higher compared to the prevalence estimated (31.0–40.0%) by Zvinorova et al., (Zvinorova et al., 2016) in Zimbabwe and Jegede et al., (Jegede et al., 2015) in Nigeria. The high prevalence of GINs is due to the warm and humid environmental condition of Bangladesh, which helps in development, survival and transmission of pre-parasitic stages of parasitic nematodes (Soulsby, 1982; Urquhart et al., 1996). However, the actual prevalence is supposed to be higher than the observed prevalence because animals having no fecal egg count (FEC) does not mean that they are not infected. By fecal examination, it was not possible to determine immature or the developmental stage of the parasites. Several other factors, such as low parasitic burden, particular portion of collected fecal sample, physiological condition of animal and the method used for FEC may not reveal the actual infection rate through coprology (Storey, 2015).

In our study, >50% goats were found infected with strongyles nematodes. Previous studies on the epidemiology of GI parasites have also reported *strongyles* as the most prevalent group of nematodes in Bangladesh (Sangma et al., 2013) and abroad (Rajpoot et al., 2017). The high biotic potential nature of strongyles is conducive to the rapid contamination of pasture by larvae, resulting in subsequent the high prevalence of strongyles infection (Bowman, 2014).

Table 8
Results of final multivariable analysis of potential risk factors associated with GI nematode infection in goats.

Risk factors	OR	95% CI	*p*-Value
Breed (other than Black Bengal)	1.64	1.25–2.14	0.000*
Body condition (animals in poor condition)	2.07	1.72–2.5	0.000*
Rearing system (backyard)	2.90	1.75–3.10	0.000*
Housing (muddy)	1.39	1.05–1.67	0.001*
Education level (illiterate)	1.45	1.14–1.85	0.002*

OR, odds ratio; CI, confidence interval.
* Significant ($p < 0.05$).

We noted that females were more susceptible to nematode infections than males which might be associated with the physiological stresses, such as pregnancy and lactation. It is evident that pregnancy greatly influences both innate and adaptive immunity (Mandonnet et al., 2005). High rise of nematode burdens around parturition, especially two weeks before parturition to eight weeks after, known as peri-parturient rise. This plays an important role in pasture contamination, resulting in the transfer of infection to susceptible animals (Schoenian, 2012).

We observed young animals (1–6 months and $>$6–18 months) were comparatively more prone to parasitic infection than adults ($>$18 month). The young are more susceptible to nematodes in pastures than adults because they are immunologically naive (Biu et al., 2009) and less capable of preventing parasite establishment. In this study, interestingly, we found that the mean FECs declined gradually with the increase of the age of animals which is substantiated by the previous findings (Odoi et al., 2007; Tariq et al., 2008). However, the protective effect in adult animals is attributed to building up immunity through the frequent exposure of the infectious agent leading to the expulsion of parasites, and the phenomenon is known as self-cure, especially observed in GI nematodes (Fisher and Say, 1989).

Interestingly, Black Bengal goats were found less susceptible to GINs than other breeds of goats which is supported by the findings of Bacha (Bacha, 2014). Genetic background of the Black Bengal goats may have contributed to the lower prevalence of GINs in this breed.

Prevalence and parasitic load were more in non-breeding male animals than breeding males. The result could not be compared due to paucity of relevant literature. Yet, it is assumed that farmers give special attention, such as additional feed supplement to breeding animals.

The study revealed a highly significant relationship ($p<0.001$) between the animals in poor condition and the prevalence of infection. It is documented that poor health status of the host enhances the establishment of higher worm burdens and increasing the pathogenicity of the parasites (Taylor et al., 2007; Bakunzi et al., 2013). However, the fecundity of parasites is usually increased in animals with poor condition (Etter et al., 1999).

We found the prevalence of GI nematodes were significantly higher in backyard animals. The previous findings showed that the traditional husbandry system (backyard system) accelerated nematode infections in small ruminants (Rabbi et al., 2013). There was a positive association between backyard animals and FEC due to the increased risk of continuous infection and re-infection from heavily contaminated pasture. In contrast, in semi- intensive systems, animals are kept in a confined area with access to selective grass fields, and additional nutrient supplements are provided. Therefore, there is a less opportunity for these animals to get parasitic infection. Additional nutrient supplementation also improves health and bootstrap immunity of animals against parasites, including GI nematodes, thus, the chance of gaining infection from pasture is minimal.

Flock size was detected as an important factor and prevalence and mean FECs were found to decrease when flock size was increased which conforms to the findings of Kantzoura (Kantzoura et al., 2012). Large flock size is mainly maintained in organized farming condition where proper sanitation is maintained and adequate living space, sufficient nutrition/supplementary feeding and necessary preventive measures are accurately provided since they are commercially reared.

The housing system is a potential risk factor associated with GINs in goats, conforming the report by Hassan (Hassan et al., 2011), which describes the muddy flooring as the predisposing factor of GINs infection. It is difficult to maintain strict hygiene in muddy floor since they get soiled easily with feces and urine making the area favorable to the development, survival and transmission of pre-parasitic stages of parasitic nematodes (Urquhart et al., 1996).

No significant variation was found between anthelmintic used (56.9%) and unused groups (62.5%) of animals. Most of the farmers in Bangladesh lack formal education, as a result they practice salvage treatment whereby only animals showing obvious clinical disease are treated. Farmers generally use albendazole, levamisole and ivermectin and seldom they follow the recommended dose and treatment schedule prescribed by any registered veterinarians. Additionally, the treatment is often based on guesstimate of animal weight by the farmers which sometimes lead to under- or over-dosing, a key player of developing anthelmintic resistance.

Seasons played a significant role in GINs infection in sheep and goats. The external environment, such as temperature, rainfall and relative humidity greatly influenced the hatching of eggs and survival of the infective stage of larvae. A favorable environment (adequate moisture) in the rainy season helps developing pre-parasitic stages of parasites or reduces the pre-patent period and increases larval population (Magona and Musisi, 2002). Peak FECs were also observed in the rainy season and continued in the cool-dry season with low level, when environmental conditions precluded the development and survival of their pre-parasitic stages (Taylor et al., 2007; Urquhart et al., 1996).

The prevalence and intensity of GINs were significantly associated with the lack of proper education of the farmers. Our study revealed that the level of awareness of farmers about GI nematodes, their mode of transmission and control were very low. Farmers were less interested in receiving veterinary services for improving their management systems due to a lack of financial solvency. Also, the majority of the farmers were from poor educational background, thus they were not aware of proper management systems or deworming schedules. Farmers with the lack of knowledge and perception about GINs are attributed to the poor health management of animals (Odoi et al., 2007; Kantzoura et al., 2012).

In conclusion, GINs infections in goats are endemic in Bangladesh, and *Haemonchus* spp. is the most prevalent parasite among the identified GINs. The present study also reveals the risk factors of GINs in goats, such as other breed than Black Bengal, animals in poor condition, backyard rearing, muddy housing and illiterate farmers. It is necessary to improve awareness of the disease as well as its impacts on animal health and productivity by increasing the education level of the farmers. Moreover, the findings have potentials to help formulate strategic control program against GINs in goats.

Declaration of competing interest

The authors declare no conflicts of interests.

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