Prevalence and Risk Factors of Lung Worm Infection in Small Ruminants in Selected Districts of Wolaita Zone, Snnprs, Ethiopia

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Research Article

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Abstract

The lungworm is an important parasitic nematode of small ruminants that infects the lower respiratory tract and is associated with high mortality and morbidity. However, the level of lungworm infection in the study districts is not known. A cross-sectional study was conducted from December 2019 to June 2020 in selected Districts of Wolaita Zone with the objectives of determining the prevalence of lungworm infection and associated risk factors. Modified Baermann techniques were used for identification of the lungworms from fecal samples. A total of 742 fecal samples from 443 sheep and 299 goats were collected and examined. Lungworms were detected in 271 (36.52%) samples. The parasites infected 192 (43.34%) and 79 (26.42%) of sheep and goats respectively. Lungworm species Dictyocaulus filaria, Protostrongylus rufescens and Muellerius capillaries were identified in 114 (15.36%), 68 (9.16%) and 57 (7.68%) fecal samples respectively. Mixed infection by two or more above species was noted in 32 (4.31%) of the samples. Among the epidemiological factors examined, agro-ecology, management system, and season showed statistically significant differences (P < 0.05) with overall lungworm prevalence in sheep and goats. On the other hand, lungworm infection among sexes, age groups and body condition scores showed no statistically significant difference (P > 0.05). The present study indicated that lungworm infection was a common problem for sheep and goats in the study area. So, measures like de-worming, early treatment and improving animal husbandry should be practiced.

Introduction

1.1. Background

Ethiopia has a large small ruminant population which is estimated at around 31.30 million sheep and 32.74 million goats (CSA 2020). Small ruminants provide 33% of meat and 14% of milk consumption, and account for 40% of cash income and 19% of the household meat consumption in the central highlands where mixed crop livestock production system is practiced (Asaye and Alemneh 2015). Small ruminants are especially relevant in the more extreme climates, and they are noted for their ability to convert low opportunity cost feed into high value products including meat, milk, fiber, manure and hides (USAID 2016). In Ethiopia, despite a larger population, the productivity of small ruminant farmers is quite low (Zeryehun and Degefaw 2017), and the farmers’ economic benefits are modest due to disease, poor nutrition, poorly designed animal production systems, and inadequate veterinary services (Sissay et al. 2007).

Small ruminant lung worm parasites are extremely common, one of the biggest production bottlenecks, and prominent in many tropical and subtropical locations around the world, where conditions are almost ideal for their survival and growth (Zeryehun and Degefaw 2017). Dictyocaulus filaria, Protostrongylus rufescens, and Muellerius capillaries are the culprits behind small ruminant lungworm infections, which are also known as verminous bronchitis or verminous pneumonia (López and Martinson 2017). Sheep and goats can get a chronic and protracted infection called verminous pneumonia. As a result of an infection in the lower respiratory tract, which can cause either bronchitis or pneumonia or both, it is
clinically defined by respiratory discomfort and pathologically by bronchitis and bronchopneumonia (Miller et al. 2012; Chakraborty et al. 2014).

The clinical signs of infected animals with lungworm can be less obvious than signs of other livestock diseases. Partly for this reason, infections with gastrointestinal and other helminthes parasites are among the most neglected areas of veterinary care in much of the developing world. It has been established that high prevalence of lungworm infection associated with poor production and unthriftiness (Hansen and Perry 1994). A number of factors can affect lungworm infection rates in small ruminants, including the climate of the area, altitude, intermediate hosts, and favorable ecological conditions such as moisture, temperature, and marshy areas for grazing, as well as sheep and goat management systems (Asmare et al. 2018).

Due to Ethiopia’s heavy rainfall and humidity, lungworm infection in small ruminants is typically high, especially in the highlands. These discrepancies in the general prevalence rate in various regions could be brought on by variations in the animal’s management practices, nutritional status, immunity level, rainfall, humidity, temperature, and examination season in their respective study areas (Alelu et al. 2006). Additionally, the number of infectious larvae consumed, the immunological system of the animals, and the position of the lungworms within the respiratory tract all affect how pathogenic they are (López and Martinson 2017).

Small ruminants are economically very significant animals that are sometimes considered immediate sources of cash for smallholder families. These economically significant animals suffer from lungworm infection, a parasitic disease. In spite of the fact that the parasite is a problem throughout Ethiopia, it is more prevalent in highland regions because of inadequate grazing and overcrowding, improper anthelmintic use, anthelmintic resistance, management issues, a lack of societal awareness, and the disease’s complicity due to its less obvious symptoms compared to other parasitic diseases. These factors have a negative impact on livestock, production, the economy, livelihoods, and livelihood economy. In southern parts of Ethiopia, as some researchers noted (Mekuria et al. 2014), there is a lack of information on published research that could be of interest to animal owners and other organizations. Thus, the objectives of this study were to estimate the overall prevalence of lung worm infection in small ruminants and to assess associated risk factors.

Material And Methods

3.1. Description of the Study Area

The study was conducted in Sodo Zuria, Damot Gale and Humbo Districts in Wolaita zone, SNNPRS, Ethiopia. These Districts are located at a distance of 336 km, 318 km and 356 km south of Addis Ababa between the coordinates of 6° 53’ 30” and 7° 4’ 30”N Latitude, 37° 48’ 0” and 37° 59’ 0”E Longitude; 6° 48’ 0” and 6° 59’ 0” N Latitude, 37° 37’ 0” and 37° 48’ 0” E Longitude and 6°30’ 0” and 7°0’ 0” N latitude and 37°30’ 0” and 38°10’ 0” E longitude respectively (Fig. 1). The altitude of Sodo Zuria, Damot Gale and
humbo Districts is 1500 to 3200, 1500 to 2850 and 1001 to 2500 m.a.s.l and the average temperature varies between 15°c to 30°c, 12°c to 24°c and 12.6°c to 20°c and average annual rainfall of 1201 to 1600 mm, 1001 to 1400 and 1000mm to 1200mm and respectively. Sodo Zuria, Damot Gale and Humbo Districts has a livestock population of 234,120 cattle, 40,873 sheep, 13,833 goat, 118,289 poultry, 6,087 donkey, 58 hoarse and 32 mules; 135,864 cattle, 39,758 sheep, 12,190 goats, 182,241 poultry, 16,128 donkeys, 1,543 hoarse and 1,103 mules and 173,569 cattle, 21,161 sheep, 42,739 goat, 197,532 poultry, 28067 donkey, 1,159 horse and 44123 mule respectively (WZFEDD 2019).

3.2. Study Population

In this study, sheep and goats were kept under extensive and semi-intensive management systems consisting of different ages, sexes and body conditions and they were selected from 12 selected rural kebeles.

3.3. Study Design

Cross-sectional study design was carried out from December 2019 to June 2020 to estimate the prevalence and associated risk factors of small ruminants’ lung worm infection.

3.4. Sampling Techniques and Sample Size Determination

Multistage and stratified random sampling techniques were used to select the study area and sample the study animals. Using multistage sampling technique, Zone was selected as primary stage, Districts as secondary stage and Kebeles as tertiary stage. Three Districts and twelve Kebeles; four from each study District were purposely taken from Woliata Zone based on transportation access, agro-ecology and study animal population numbers.

Stratified random sampling was used to classify the study animals into strata. In the study, small ruminants were stratified into goats and sheep. After stratification, animals were sampled from respective kebeles using a simple random sampling technique. For this reason, the goat and sheep numbers in three districts were gathered from secondary data recorded in the livestock and fishery department of Wolaita Zone as well as respective districts and kebeles to reach the intended sample size. In Sodo Zuria, 13, 833 goats and 40,873 sheep a total of 54,706 were present; in Damot Gale, 12,190 goats and 39,758 sheep a total of 51,948 were found and in Humbo District 42,739 goats and 21,161 a total of 63,900 small ruminant population was present (WZFEDD 2019). Therefore, the sample size required for this study was determined depending on the expected prevalence of small ruminant lung worm infection and the desired absolute precision based on Thrusfield (Thrusfield and Christley 2018) by the following formula.

\[ n = \frac{1.96^2 \times Pexp (1 - Pexp)}{d^2} \]

Where: \( n \) = required sample size; \( Pexp \) = expected prevalence; \( d \) = desired absolute precision (5%). Since there were published data at the national level by Asmare et al. (2018) who reported 40.8% pooled
estimates of lungworm infection in small ruminants in Ethiopia. Thus, the expected pooled prevalence for this study was 40.8%. According to the formula, the calculated sample size was 371. For increased precision, the sample size was doubled. Therefore, the total sample size required for this study was 742.

Considering the difference in goat and sheep populations in the selected three Districts and even within twelve Kebeles, the sample size was allocated proportionally based on goat and sheep populations. As the result, 24% (178) sheep and 8% (60) goats a total 238 small ruminants from Sodo Zuria; 23% (173) sheep and 7% (53) goats a total 226 from Damot Gale and 13% (92) sheep and 25% (186) goats a total 278 from Humbo Districts were selected, then sampled.

Likewise the small ruminant population number in each twelve kebeles was identified and taken from Wolaita Zone livestock and fishery department. In Sodo Zuria Districts; Waraza Lasho Kebele has 2950 sheep and 520 goats and total was 3470; Dalbo Wogene has 2180 sheep and 362 goats and total was 2,542; Kuto Sorphela has 3835 sheep and 1208 goats and total was 5,043 and Dalbo Atwaro has 2980 sheep and 196 goats and total was 3176. In Damot Gale District: Shasha Gale has 2060 sheep and 426 goats and total was 2486; Gacheno has 2416 sheep and 670 goats and total was 3086; Harto Kontolo has 2196 sheep and 978 goats and total was 3174 and Harto Burkuto has 2350 sheep and 1236 goats and total was 3586. In Humbo Districts: Ampo Koysha has 920 sheep and 1858 goats and total was 2778: Ela Kebela has 846 sheep and 2592 goats and total was 3438: Ambe Shoya has 1308 sheep and 3210 goats and total was 4,518 and Koysha Wongela has 1446 sheep and 2254 goats and total was 3700.

Samples were distributed proportionally based on the number of small ruminants in each kebele. Therefore, in Sodo Zuria Districts: 18% (44) sheep and 6% (14) goats from Waraza Lasho was sampled, 14% (33) sheep and 4% (10) goats from Dalbo Wogene, 24% (57) sheep and 13% (31) goats from Kuto Sorphela and 18% (44) sheep and 3% (5) goats from Dalbo Atwaro was sampled; in Damot Gale District: 18% (40) sheep and 3% (7) goats from Shasha Gale, 20% (46) sheep and 5% (11) goats from Gacheno, 18% (42) sheep and 7% (15) goats from Harto Burkuto and 20% (45) sheep and 9% (15) goats from Harto Kontolo; and in Humbo District: 7% (19) sheep and 13% (35) goats from Ampo Koysh, 6% (17) sheep and 17% (49) goats from Ela Kebela, 10% (27) sheep and 22% (60) goats from Ambe Shoya and 10% (29) sheep and 15% (42) goats from Koysha Wengela were sampled.

### 3.5. Data Collection

#### 3.5.1. Animal level data collection

During sampling in the field, age, sex, species, body condition, agro-ecology, season and management system of the animals were recorded in a pre-formed sample collection format. Age of sheep and goats is determined by teeth according to ESGPIP (ESGPIP 2008). Those sheep and goats that have milk teeth that have started to wear down, or are fully spread out were classified as young (less than or equal to one year) and those with erupted and growing 1st pair of permanent teeth were classified as adult (greater than or equal to one year). Body condition scoring was determined by differences in relative body
fatness. Based on this body fatness, animals were categorized into three categories: poor, medium and good, according to the ESGPIP (2008, 2009).

### 3.5.2. Parasitological data collection

Fecal samples were collected directly from the rectum of animals using a disposable plastic glove for the coprological examination. The fecal sample was put into screw-capped glass bottles and properly packed. All fecal samples were clearly labeled with the date of sampling, type of sample and the identification number of the animal (Radostits et al. 2007); then the fecal sample was transported to Sodo Regional Veterinary Laboratory for identification of the larvae (L1) of lung worms.

### 3.6. Parasitological Examination

Technique recommended by Urquhart et al. (1996) was tasked for identification of lungworm species from the collected samples. Using the Baerman method of detecting lungworm larvae in the laboratory, 5-10g of fresh feces were weighed from each sample for the extraction of the first stage (L1). Feces were completely enclosed in gauze fitted with two applicator sticks which passed through the rubber band and rested on the edges of the funnel glass. In a panel glass filled with lukewarm water, the sample was submerged until the corner of the gauze did not hang over the edge of the funnel. After leaving the apparatus overnight, the sediment was carefully collected into a test tube and centrifuged for 3 minutes at 1500 rpm. Then after, the supernatant was slowly discarded and the sediment examined under the low power of a compound microscope (Anne and Gray 2006).

Parasite larvae (L1) were identified by their morphological differences under a microscope. *Dictyocaulus filaria* larvae (L1) are distinguished from the other two lungworms by the characteristic cuticular knob on the anterior extremity, the large size and blunt tail, and intestinal inclusions on the larvae (L1). While the larvae of *Protostrongylus rufescens* and *Muellerius capillaries* are differentiated by their characteristic features at the tip of their tails. In both *P. rufescens* and *M. capillaris*, L1 is small and lacks an anterior cuticular knob. Further, L1 of *M. capillaris* has a dorsal spine at the pointed wave tail, but L1 of *P. rufescens* lacks a dorsal spine (Taylor et al. 2007).

### 3.7. Data Management and Analysis

The well-organized data and result of parasitological examination was entered and managed in MS Excel work sheet and analyzed by using STATA version 14.2. Descriptive statistics was performed to estimate the overall prevalence of the disease in small ruminants and the prevalence of parasitic infection by animal species as well as the prevalence of each parasitic species. The prevalence of lungworm infection was calculated by dividing positive samples for the total number of samples examined. Logistic regression was employed to compute odds ratios (OR) and 95% confidence interval (CI) in order to determine the strength of association between the statistically significant risk factors and parasite positivity. A backward step-by-step selection method was also computed to identify predictors. A p-value less than 0.05 at 95% confidence level was considered significant for all analyses.
Results

5.1. Overall Prevalence

A total of 742 small ruminants that belong to different age groups, sexes, and agro-ecologies and are managed in extensive and semi-intensive systems were scrutinized for lungworm infection in this study. About 742 (443 sheep and 299 goats) fecal samples were examined of which 271 were positive for lungworms with an overall prevalence of 36.52% (Table 1).

In the present study prevalence of lungworm infection was much greater in sheep (43.34%) than goats (26.42%). Age-wise, the prevalence was 37.76% among young (< 1 year old) and 35.47% among adults (> 1 year old). Concerning sex, this study showethat a higher prevalence of lungworm infection was observed in females (38.67%) than males (32.84%). In the cases of body condition, the prevalence of lungworm infection was higher (39.60%) in animals of poor body condition than those of medium (37.46%) and good (30.23%). For agro-ecology, prevalence of lungworm infection was higher in highland (45.37%) than in midland (42.47%) and lowland (24.47%) (Table 1).

5.2. Proportions of Identified Lungworm Species

The main lung worm species identified in this study based on coproscopy were *Dictyocaulus filaria*, *Protostrongylus rufescens* and *Muellerius capillaries*. Larva (L1) is the predominant and obvious species of lung worms detected through fecal samples from small ruminants, and it was identified as a mixed infection with one or two other species. The proportion of different species was found to be different among positive fecal samples of small ruminants. It was found that 15.36% (114/742), 9.16% (68/742), 7.68% (57/742) and 4.31% (32/742) of the small ruminants were parasitized by *Dictyocaulus filaria*, *Protostrongylus rufescens*, *Muellerius capillaries* and mixed infection of lung worms respectively as shown (Table 2).

5.3. Univariable Logistic Regression Analysis of Associated Risk Factors

Univariable logistic regression analysis was used to determine single predictors having crude significance levels at p value < 0.25 that were of a prior interest for further multivariable logistic regression analysis by using the backward step wise selection method (Table 2).

5.4. Multivariable Logistic Regression Analysis of Associated Risk Factors

During multivariable logistic regression analysis, backward step-wise regression analysis was used to select those predictors that predispose to the occurrence of lungworm infection in small ruminants in this study (Table 4). In the backward step-by-step regression analysis, the first step was selecting predictors with crude significance levels of p < 0.25 in the univariable logistic regression analysis. Then, in the
second step multiple predictor models were fit by using step one. Finally, multivariable model was fitted containing predictors with adjusted significance levels at p value < 0.25 from step two.

The multivariable analysis of lungworm infection with species of animal showed that there was a significant difference between sheep and goats (p < 0.05). It was observed that the odd of lungworm infection was 29.4% less likely in goats compared with sheep. In relation to agro-ecology, the prevalence of lungworm infection in various agro-ecologies varied significantly by altitude (p < 0.05). The odds of lungworm infection in those small ruminants in lowland areas were 70.4% less likely to be infected by lungworm than those small ruminants in highland areas. In contrast, the odds of lungworm infection in those small ruminants in midland area were 44.7% less likely to be infected than highland area. The odds of lungworm infection in extensively managed small ruminants were 2.46 times higher than those semi-intensively managed ruminants.

Further, those animals kept under semi-intensive management practices were fed well-balanced, palatable and nutritious feed, which increased their immunity against lungworm infections, as opposed to those kept under intensive management, which did not get enough feed, which compromised their immunity and allowed the parasites to grow and infect the animals continuously for a long period of time. With regards to the seasonal distribution, there was a significant difference between wet season and dry season (p < 0.05). Lungworm infection in wet season was (March, April, May and June) higher than dry season (December, January and February) in the current study. The odd of lungworm infection was 26.4% less likely in dry season compared with wet season.

**Discussion**

This study explicitly proved that lung worm is one of the most important respiratory tract infections of small ruminants in the districts of Sodo Zuria, Damot Gale and Humbo of the Wolaita zone of the Southern Nation Nationalities People Region, Ethiopia. Small ruminants could be infected with several lungworms. However, the prominent species that are causing of respiratory diseases are *Dictyocaulus filaria*, *Muellerius capillaris*, and *Protostrongylus rufescens*. *Dictyocaulus filaria* is the lungworm species most commonly infecting small ruminants, whereby causing poor body condition, clinical respiratory signs, and premature death. Thus, lungworm infections are serious health problems for small ruminant animals, which are likely to cause heavy economic losses.

This coproscopic study result showed an overall prevalence of lungworm infection of 36.5% in small ruminants in the study areas. This overall prevalence finding was almost in agreement with the reports of Addis et al. (2011) 33.83% in Gonder town, Regassa et al. (2010) 36.9% in Dessie and Kombolcha districts, Kassa et al. (2017) 31.2% in three districts of South Wollo, Ethiopia and Asmare et al. (2018) 40.8% meta-analytic study in Ethiopia. Comparatively, this study documented lower prevalence than the reports of Alemu et al. (2006); Abera et al. (2016); Fesseha and Mathewos (2021) who reported overall prevalence of lungworm infection in small ruminants: 53.60%, 57.6%, 44.02%, in Asella province, Bale and Arsi zone, in Durame District, Southern Ethiopia respectively. The results of this study, on the other hand,
showed a relatively higher prevalence compared to reports of Asaye and Alemneh (2015) 22.71% in Bahir Dar City, Amhara Region; and Borji et al. (2012) 10.85% in Mashhad of northeast, Iran. The climate, altitude, intermediate hosts, favorable ecological conditions, the sheep and goat management systems of the respective study areas for the development of lungworm species, differences in the sample sizes used during the various investigations, seasonal variation during the investigation period, variation in the nutritional status of the small ruminants, and other factors may all contribute to the variation in the overall prevalence of lungworm infections in small ruminants across the study sites.

In the current study, the proportion of lungworm infection was higher in sheep (43.34%) than in goats (26.42%). This finding agrees with that of Regassa et al. (2010) who reported 40.40% in sheep and 31.70% in goats in Dessie and Kombolcha districts, northeastern Ethiopia and Kadi et al. (2017) who also reported 57.40% in sheep and 31.20% in goats from Asella, Arsi Zone of South East Ethiopia. However, this finding contradicts that of Alemu et al. (2006) who reported a higher proportion of goats (50.70%) than sheep (24.46%) in northeastern Ethiopia and Tenaw and Jemberu (2018) also reported a higher percentage of goats (36.3%) than sheep (15.5%). The possible explanation for this variation in proportion among the two species of small ruminants might arise from the difference in grazing behavior of the two species of animals. The fact that sheep are predominantly grazers means that they have a greater chance of ingesting large numbers of infective larvae (L3) than goats. Since goats browse, they are less likely to ingest infective larvae.

In the current study, 37.76% of cases of lungworm were found in young animals (1 year old) and 35.47% of cases in adults (> 1 year old). This finding was in concomitant with Asaye and Alemneh (2015) who documented higher prevalence of lung worm infection in young animals (36.5%) than adults (29.5%) in and around Bahir Dar City, Amhara Regional State, Ethiopia; Negash et al. (2018) who reported 53.3% in young and 36.3% in adult in Gedeb Asasa district West Arsi Zone, Ethiopia. However, this finding was not in line with findings reported by Kdie et al. (2017) who found 47.80% in young and 51.50% in adult in Asela, Arsi Zone, Southeast, Ethiopia, and Regassa et al. (2010) who reported 22.5% in young and 77.5% in adult in Dessie and Kombolcha districts, northeastern Ethiopia. Because an animal’s vulnerability to lungworm infection declines with age, young animals are more likely to have the infection than young adults. This indicates that due to previous exposure to lungworm infection, mature animals have developed immunity. Because they are exposed less frequently than older animals, young animals are much more vulnerable (Abdeta and Degefa 2020). Furthermore, the difference could be explained by the proportion of young and adult animals sampled in each study; since the study was conducted outdoors, more adult animals were sampled than young animals.

The major lung worm species coprologically identified in small ruminants were *Dictyocaulus filaria*, *Protostrongylus rufescens* and *Muellerius capillaries*. *D. filaria* was the predominant species in the study area followed by *Protostrongylus rufescens*. This finding is supported by Alemu et al. (2006)d pez and Martinson (2017) who found *D. filaria* to be prevalent. In advance, Asmare et al. (2018) confirmed the predominance of *D. filaria* by systematic review and meta-analysis in Ethiopia. The possible explanation for the prevalence of *D. filaria* in the study area might be related with the life cycles of the parasites. Thus,
*D. filaria* has a direct life cycle and requires shorter time to develop to an infective stage. According to Hansen and Perry (1994) and López and Martinson (2017) after ingestion, the larvae of this parasite can be shed with feces within 5 weeks. In contrast to *D. filaria*, *P. rufescens* and *M. capillaris* exhibit epidemiologically complex transmission patterns including the host, the parasite, and an intermediate host.

It was found that the odds of lungworm infection were 70.6% higher in sheep than in goats in this investigation. This finding is in line with the report by Regassa et al. (2010) who stated the odd of lungworm infection were 2 times higher in sheep compared with goats in Dessie and Kombolcha districts, North-eastern Ethiopia. However, it disagrees with previous reports that indicated higher odds of lungworm infection (3: 2–5; p < 0.001) in goats than sheep by Tenaw and Jemberu (2018); Alemu et al. (2006) and Borji et al. (2012) who stated goats are more susceptible than sheep. Goats are more susceptible to *Dictyocaulus laria*, according to a controlled experimental investigation (Sharma 1994). Despite this susceptibility being demonstrated during experiments, they are naturally browsers in their feeding habits. As a result, their risk of contracting lungworms is probably lower than that of sheep, which typically graze and are therefore anticipated to have a lower incidence of lungworms. This study claims that the reason this was not detected was because goats were compelled to graze due to a lack of browsing forages in the study location, which may have increased exposure to lungworms.

With regard to agro-ecology, the odds of lungworm infection in those small ruminants in lowland areas were 70.4% less likely to be infected by lungworm than those small ruminants in highland areas. This is in agreement with Alemu et al. (2006), who reported lower odds of prevalence for *D. filaria* and *Muellerius capillaris* at low altitudes when compared to high altitudes in north eastern Ethiopia. Furthermore, Asmare et al. (2018) and Yimer and Desie (2016) showed different prevalence rates among various agro-ecological systems in northern Ethiopia. This might be due to the effect of altitude which is attributable to climatic parameters. That is the survival and development of lungworm larvae is favored by low moisture content and high humidity.

With regard to management systems, the occurrence of lungworm infection was significantly different. The odds of lungworm infection in extensively managed small ruminants were 2.46 times higher than those in semi-intensively managed ruminants. This result is consistent with that of Abebe et al. (2016). Small ruminants kept in extensive and semi-intensive managed systems showed a statistically significant difference, according to a study by Alemu et al. (2006). In this case, animals managed under extensive management systems have a higher chance of contracting lungworm infection than animals managed under semi-intensive management systems because animals under extensive management systems repeatedly graze on the pasture, which increases the chances of contracting lungworms, but in cases of semi-intensive management, animals have a low chance of pasture contamination, which leads to a low risk of lungworm infection. In addition, animals kept in semi-intensive systems afford palatable and nourishing adlib feed, which increases their resistance to infections. In contrast, animals kept in extensively managed systems do not feed adequate feed, which could compromise their resistance and expose them to parasite larvae on a constant basis.
This study found that lungworm infections are significantly different during the wet season and the dry season, based on the seasonal distribution of lungworm infections. Lungworm infection in the wet season was higher than in the dry season in this study area. The odds of lungworm infection were 26.4% less likely in the dry season compared with the wet season. This finding coincides with previous reports by Regassa et al. (2010). This could imply that epidemiology of lungworms indicates that a damp and cool environment is very suitable for the development of *D. filaria* and the third stage larva (L3) is resistant to cold. The dung beetles facilitate the spread of *D. filaria* larvae under favorable conditions, but under dry conditions, the larvae may be inhibited in the lung. Moisture is a vital factor in determining the survival and availability of parasites (Kołodziej-Sobocińska 2019). Thus, relatively higher records of lungworm infection during the wet season could also be due to the fact that the survival and development of larvae is favored by low moisture and high humidity.

**Conclusion**

This study showed that 36.5 percent of small ruminants had lungworm infection in small ruminants. Of the small ruminants infected, 43.34% were sheep and 26.42% were goats, which were invariably infected with different species of lungworms. Hence, lungworm infections are extremely common in the study area and are serious health problems for small ruminant animals, which are likely to cause heavy economic losses. The lungworms species recorded in this study were *Dictyocaulus filaria*, *Protostrongylus rufescens* and *Mullerius capillaris*. The most common infection was by *Dictyocaulus filaria*, but mixed infections were also observed. Statistical tests were used to analyze a number of risk factors affecting prevalence, including species, age groups, sexes, body condition, agro-ecology, management method, and season. The prevalence of lungworm infection varied statistically significantly for the risk factors such species, agroecology, management system, and season. On the other hand, there was no statistically significant variation in the prevalence of lungworm infection among sexes, age groups, and physical conditions. Hence, the prevention and management of lungworm infections should be taken into account. To enable the creation of a useful control strategy in the study area, further research on seasonal risk variables is required.

**Declarations**

**ETHICAL CONSIDERATION**

This study was carried out strictly in accordance with ethical considerations and by taking official permission letter from the Arba Minch University, ethics and welfare committee. Therefore, for this study in study area ethnic differences, societal cultures, and permission of society should be accepted and animal welfare and humane action should be under consideration.

**CONSENT FOR PUBLICATION**

Authors have read and agreed to the published version of the manuscript.
COMPETING INTERESTS

The authors declare no competing interest

FUNDING DECLARATION

This research received no external funding for publication.

AUTHORS CONTRIBUTION

Wondimu Tessema contribution was conceptualization, writing overall research and methodology. Minale Getachew contributed research title selection, editing, data curation and supervision. Ephrem Tora contributed revision, editing, and data curation.

AVAILABILITY OF DATA

The data set generated and analyzed in the current study is available from the corresponding author upon reasonable request.

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Tables

Tables 1 to 4 are available in the Supplementary Files section.

Figures
Figure 1
Map of Ethiopia displaying the locations of study areas

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

- Tables.docx