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Endoparasitic infections and prevention measures in sheep and goats under mountain farming conditions in Northern Italy

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ABSTRACT

In mountainous areas, where small ruminants form an integral part of livestock farming, an effective control of parasites is of high importance, because the animals are grazing on communal pasture land during the summer months. But knowledge on the infection status of the animals, which is needed for an effective control, is very limited in these areas. Therefore, this study aimed to assess the prevalence of endoparasitic infections and the use of preventive measures in sheep and goat farms in South Tyrol, a mountainous region of Northern Italy. A questionnaire was used to collect information on farm structure and management as well as routine parasite control measures. Following the survey, a total of 3536 individual fecal samples from 123 sheep and goat flocks were analysed over three periods in autumn 2015, spring and autumn 2016 with routine methods including fecal egg counts (FEC) and oocysts counts (FOC). Animals were classified into < 6 months, 7–12 months and > 12 months of age. Goat flocks had an average herd size of 31 (range 5–125) and sheep flocks of 28 animals (range 2–100). Mountain sheep and goat breeds were dominant. More than 60% of the sheep and 40% the goat flocks were grazed on communal summer pastures at altitudes > 1500 m a.s.l. Both sheep and goat farmers perceived gastrointestinal strongylid nematodes (GIN) as the most frequent parasites. Only 16% of the sheep and 30% of the goat farmers ever before this study did coprological examinations. More than 90% of the farms applied anthelmintic treatments; usually once (sheep: 32%, goats: 53%) or twice (sheep: 68%, goats: 42%) per year. Independent of the season, macrocyclic lactones were the most commonly used anthelmintics. More than 30% of the sheep-12 months and 16% > 12 months were GIN-negative. Sheep < 6 months had a lower FEC than animals of both other age classes ($P < 0.05$). In goats, 15.9% of the samples collected from animals < 6 months were GIN-free. Age classes, however, did not differ for FEC in goats ($P > 0.05$). Third-stage larvae identified in coprocultures were dominated by *Teladorsagia/Trichostrongylus* in both sheep (56.5 ± 24.5%) and goats (60.5 ± 25.8%). While in sheep lambs had a higher FOC than both other age classes, kids did not differ from goats at an age of 7–12 months but only from those > 12 months ($P < 0.05$). In sheep, tapeworms were found in around 13% in both groups below 12 months and 6.5% in sheep > 12 months, while these parasites were identified in 18.5, 7.3 and 5.7% in goats < 6 months, 7–12 months and > 12 months, respectively. The prevalence of lungworms at flock level varied between seasons from 18 to 50% in sheep and 44–78% in goats. This first report on endoparasitic infections of sheep and goats in the mountainous region of South Tyrol reveals a high prevalence of endoparasites, especially GIN at a medium infection level, tapeworms and lungworms. Anthelmintics are regularly used, while fecal sampling for selective treatment only exceptionally. Therefore, parasite control measures should be optimized to reduce the risk for the development of anthelmintic resistance, which was already reported from neighboring regions.

1. Introduction

In many mountain regions small ruminants constitute an integral part of livestock farming and populations remained stable during the last years (Di Cerbo et al., 2010; Ringdorfer and Finotti, 2015). Beside meat and milk production, sheep and goat farming – mostly conducted by small-scale farms – play an important role for the conservation of mountainous landscapes, especially at high altitudes and steep slopes and are closely linked to agritourism activities (MacDonald et al., 2000; Ringdorfer and Finotti, 2015). Compared to more intensive production systems, autochtonous breeds are still widely used in mountain regions and for many of the farmers breeding activities rather than economic benefits are a major motivation to substantiate livestock farming (Manfredi et al., 2010). Specific for small ruminant farming in

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mountain areas is the extensive use of communal alpine pastures during summer months and a distinct barn period during winter months. An alteration between pasture areas at lower altitudes in spring and autumn and communal summer pastures at high altitudes might impact parasitological infections, even though is knowledge in this specific field limited. The management of refugia is complicated and common strategies such as targeted (selective) treatments (Charlier et al., 2014) to combat parasitic infections and especially limit the spread of resistant parasites are not widely adopted by farmers using communal grazing land. Furthermore, it has to be considered that mountain livestock farming is partly impacted by a lack of infrastructures and services (López-i-Gelats et al., 2011), including for example veterinary services.

However, infections with helminths in small ruminants are of economic importance not only in mountain areas but worldwide and cause deaths, reduced weight gains, decreased milk yields and discarded organs at slaughter (Gauly et al., 2004; Hoste et al., 2010; Rinaldi et al., 2007). In dairy goats, helminth infections can lead to a decrease of the milk yield by almost 20% (Chartier et al., 2000). Furthermore, economical losses are related to the increased feed demand and additional costs for medical treatments. Beside gastrointestinal strongylid nematodes (GIN), *Eimeria* spp. infections belong to the most important parasitic infections in goat flocks leading even to deaths (Matthews, 1991). Generally, infections are higher in goats than in sheep (Hoste et al., 2010). The major reason is that immunity also develops during the first year of age, but is less pronounced than in sheep (Hoste et al., 2008). Another reason may be that the dosage used by veterinarians or farmers in goats is usually the same as for sheep, but needs to be higher (Manfredi et al., 2010). In a recent study of Di Cerbo et al. (2010) conducted in Lombardy (Northern Italy), GIN were found in almost all goats.

Because parasitic infections constitute such a problem for small ruminants causing economic losses (Waller, 2006a,b), special attention has to be given to the available control measures. Most commonly, infections are controlled by applying anthelmintics (Domke et al., 2012; Manfredi et al., 2010; Zanzani et al., 2014). However, their decreasing efficiency caused by its regular use has gained interest and anthelmintic resistances in small ruminants are proven in a growing number of countries worldwide (Domke et al., 2012; Holm et al., 2014; Van den Brom et al., 2013; Schoiswohl et al., 2017; Kupčinskas et al., 2015; Čerňanská et al., 2006). In Central Italy, Traversa et al. (2007) already reported multiple resistances in gastrointestinal trichostrongylids of sheep. Recently, Zanzani et al. (2014) found an alarming number of dairy goat flocks in Northern Italy with problems of anthelmintic resistance and emphasized the need for strategies to prevent the development of anthelmintic resistance. The application of alternative prevention measures such as selection for genetic resistance, feeding of plant extracts or rotational use of pasture areas which have been proven effective against GIN infections (Jackson et al., 2009; Sayers and Sweeney, 2005; Waller, 2006b) is limited under the specific conditions of mountain regions, which is partly due to the small scale of farms and because they are run as part-time farming or hobby activity. The use of communal land is further complicating an efficient parasite control management.

Given that for South Tyrol, a mountainous region of Northern Italy, no studies on endoparasitic infections in livestock are available, yet, this study aimed to assess the prevalence and abundance of gastrointestinal parasites (nematodes, cestodes and trematodes) and current routine prevention measures in sheep and goats of this region.

2. Materials and methods

Sampling protocols applied met the International Guiding Principles for Biomedical Research Involving Animals as issued by the Council for the International Organizations of Medical Sciences.

2.1. Farm selection and study area

Sheep and goat farmers of the province South Tyrol, Northern Italy (46.73° North, 11.29° East) were invited through an announcement in the local agricultural magazine in autumn 2015 to participate in this study. The study was also promoted by the South Tyrolean farmer association for small ruminants. First, farmers were asked to answer a questionnaire and second individual fecal samples were collected for parasitological measurements. Data from a total of 123 sheep and goat flocks raised on 103 different farms were included in the study. Farms that raised sheep and goats together or dairy and meat breeds of one species answered one questionnaire per species or breed.

2.2. Farm questionnaire

The questionnaire was designed to collect data on farm management, including husbandry system, herd size, breeds, other livestock on the farm, and sizes, elevations and management of pastures. In addition, farmers were asked for their perception of parasitic diseases and applied preventive measures against parasites. Furthermore, drenching practices were surveyed including the choice of anthelmintics, application practices, rotation of anthelmintics and the perceived effectiveness and side effects. An invitation letter to participate in the study described the purpose of the study, provided assurance of confidentiality, asked for permission to publish the anonymous responses and the willingness to participate in the fecal samplings. In total, the questionnaire consisted of 32 closed and 3 open questions.

2.3. Fecal sampling

After completion of the survey, farmers were contacted by phone to describe procedures to collect fresh fecal samples directly from the rectum of the individual animals. Twenty percent of the farmers collected the samples themselves, the remaining farms were visited by the researchers for sample collection. At each farm, at least 90% of the individuals older than 3 months were sampled. The age of the animals was recorded and classified into < 6 months, 7–12 months and > 12 months. Another pre-condition for sampling was that the animals were not treated with anthelmintics within the previous three months. A total of 3536 samples were taken in three periods, namely autumn 2015 (952 sheep and 1045 goat samples), spring 2016 (325 sheep and 615 goat samples) and autumn 2017 (421 sheep and 178 goat samples). After collection, the samples were stored cool during transportation to the laboratory and then stored at 4 °C in the refrigerator until analysis to avoid hatching of the eggs. Each sampling period lasted for approximately 2 months.

2.3.1. Parasitological measurements

Fecal egg counts (FEC) and oocyst counts (FOC) were done using a modified McMaster method (MAFF, 1986) with 60 ml of saturated NaCl solution as the flotation fluid (specific gravity = 1.2) and 4 g of feces to determine eggs per gram of feces (EPG) and *Eimeria* oocysts per gram of feces (OPG). Each egg counted represents 50 eggs per gram of feces. For tapeworms, individual animals were classified as infected if at least one tapeworm egg was identified in a sample. For further identification of nematode species, third-stage larvae (L3) were cultured with pooled feces (10–20 g) of each flock (only for farms with > 10 individual samples). L3 were recovered from the coprocultures by applying the Baermann technique (MAFF, 1986). The first 100 randomly selected L3 of each sample were identified to the generic level *Teladorsagia/Trichostrongylus, Oesophagostomum/Chabertia, Haemonchus, Nematodirus, Bunostomum* and *Cooperia* by microscopy according to MAFF (1986). The percentage of larval type was calculated on the basis of the counted L3 when fewer than 100 L3 were isolated from a sample. A pooled sample of each farm was used to detect the eggs of liver flukes applying the sedimentation test using 5–10 g of feces and larvae of lungworms applying the Baermann test using approximately 4 g of feces (MAFF, 1986).

2.3.2. Statistical analysis

The statistical analysis was performed with the use of SAS statistical package version 9.3 (SAS Institute Inc., Cary, NC, 2010). For data of the farm questionnaire frequencies were calculated at farm level separately for goats and sheep. For closed questions where more than one answer was possible, the results where expressed as the percent of the selected answer to the total number of records.

Results of the FEC were used to calculate prevalence rates for the following gastrointestinal parasites: GIN, *Strongyloides papillosus, Nematodirus* spp., *Trichuris* spp., tapeworms, *Dicrocoelium dendriticum* and *Eimeria* spp. According to Soulsby (1982), FEC values of GIN were classified into GIN-free, low (< 500 EPG), medium (500–1000 EPG) and high (> 1000 EPG). Similarly, FOC values were classified into *Eimeria*-free, low (< 1800 OPG), medium (1800–6000 OPG) and high (< 6000 OPG) according to Idris et al. (2012).

A mixed model (Proc MIXED) was applied to analyse the data of the FEC and FOC. Prior to the analysis the number of EPG and OPG were log-transformed ($\log_{10}$(EPG + 10) and $\log_{10}$(OPG + 10)). The model included the species (sheep, goat), breed nested within species, age class (lamb = < 6 months; young = 7–12 months, adult = > 12 months), sex (male, female), study season (autumn 2015, spring 2016, autumn 2016) and all two-way interactions as fixed effects and farm as random effect. Breeds were included in the model if at least 50 individual samples from at least 5 different farms were sampled. For sheep, these were Tirolean mountain sheep, Brown mountain sheep, Jura sheep, Villnösser sheep and Friesian milk sheep and for goats Passeirer mountain goat, German fawn and Saanen. Breeds that did not fulfill this requirement were combined as other breeds. Interaction effects that were not significant at $P < 0.05$ were excluded from the final model. Multiple pairwise differences were compared applying the Bonferroni correction. For ease of interpretation, all log-transformed least squares means are reported as back-transformed least squares means.

3. Results

3.1. Farm questionnaire

Farms that participated in this study were distributed over the whole province of South Tyrol. Of the 103 studied farms, 43 farms raised meat sheep only, 5 dairy sheep only, 16 meat goats only, 15 dairy goats only, 7 meat sheep and dairy goats, 1 dairy sheep and dairy goats, 4 dairy and meat goats and the remaining 12 farms raised meat sheep and meat goats together. In brief, goat flocks had an average size of 31 (range 5–125) and sheep flocks of 28 animals (range 2–100). Detailed characteristics of the farms are presented in Table 1. About 29% of the flocks of both species had herds of more than 40 animals. Regarding the breeds, 82% of the sheep and 76% of the goat farms raised only one single breed, while 15% and 18% raised two and 3% and 6% three sheep and goat breeds, respectively. The dominant sheep breeds were Tirolean mountain sheep (48.6%), Brown mountain sheep (13.8%) and Jura sheep (13.8%). In goats, the autochtonous breed Passeirer mountain goat (49.1%) and German fawn (29.1%) were dominating. Ten percent of the sheep and 26% of the goat flocks were managed according to organic farming regulations. Half of the goat farms produced milk, while this was the exception in sheep farms. Less than 15% of the sheep and 26% of the goat flocks were managed as full-time activity. The majority of the farms (sheep: 60%, goats: 55%) kept other livestock, mainly cattle, on the farm.

Seasonal grazing was practiced on all except 3 goat farms; and generally began in April to May and lasted until October to November (Table 1). Privately owned grazing areas at the farm location usually were below 1500 m a.s.l., with continuous grazing being the predominant grazing system in both sheep (39.7%) and goat (48.1%) flocks. On these pastures harrowing, fertilization and mowing were the most common management measured in both species. More than 60% of the sheep flocks were moved to communal summer pastures at altitudes > 1500 m a.s.l. In goats, only approximately 40% of the flocks were grazed on communal summer pastures and 4% on privately owned summer pastures > 1500 m a.s.l.

The farmers' perception of the occurrence of endo- and ectoparasitic infections in their flocks is presented in Table 2. For both species, 40% of the farmers mentioned that GIN have never been a problem, while another 40% answered that GIN occurred occasionally and 20% that it

Table 1
Farm characteristics of the 103 studied farms raising a total of 123 sheep and goat flocks (expressed as number of flocks).

Factor	Species	
	Sheep (n = 68 flocks)	Goat (n = 55 flocks)
Herd size (animals/herd)		
1–19	24 (35.3%)	25 (45.5%)
20–39	24 (35.3%)	14 (25.5%)
> 40	20 (29.4%)	16 (29.1%)
Breed[a]		
Jura sheep	10 (13.8%)	
Friesian milk sheep	6 (8.8%)	
Brown mountain sheep	10 (13.8%)	
Tirolean mountain sheep	35 (48.6%)	
Villnösser sheep	5 (7.0%)	
German fawn		17 (29.1%)
Passeirer mountain goat		29 (49.1%)
Saanen		5 (9.0%)
Other	6 (8.3%)	8 (12.8%)
Type of activity		
Full-time farming	10 (14.7%)	14 (25.5%)
Part-time farming	41 (60.3%)	30 (54.5%)
Hobby farming	17 (25.0%)	11 (20.0%)
Start of grazing period[b]		
February	1 (1.5%)	0 (0.0%)
March	5 (7.4%)	2 (3.8%)
April	26 (38.2%)	28 (53.8%)
May	33 (48.5%)	17 (32.7%)
June	3 (4.4%)	3 (5.8%)
July	0 (0.0%)	2 (3.8%)
End of grazing period[b]		
September	3 (4.4%)	3 (5.8%)
October	23 (33.8%)	10 (19.2%)
November	28 (41.2%)	31 (59.6%)
December	14 (20.6%)	8 (15.4%)
Altitude of privately owned grazing areas at the farm location[b]		
< 1000 m a.s.l.	20 (29.4%)	14 (26.9%)
1000–1500 m a.s.l.	25 (36.8%)	22 (42.3%)
1500–2000 m a.s.l.	13 (19.1%)	67 (11.5%)
> 2000 m a.s.l.	10 (14.7%)	10 (19.2%)
Grazing system[b]		
Strip grazing	2 (3.0%)	3 (5.8%)
Simple rotation (2–3 grazing areas)	23 (33.8%)	17 (32.7%)
Intensive rotation (4–8 grazing areas)	16 (23.5%)	7 (13.5%)
Continuous grazing	27 (39.7%)	25 (48.1%)
Measures of pasture management on privately owned pastures[a,b]		
Harrowing	62 (91.2%)	49 (94.2%)
Fertilization	35 (51.5%)	28 (53.8%)
Mowing	20 (29.4%)	22 (42.3%)
Seeding	7 (10.3%)	4 (7.7%)
Exclusion of wet areas	4 (5.9%)	2 (3.8%)
Use of summer pastures at altitudes > 1500 m a.s.l.[b]		
Privately owned	0 (0.0%)	2 (3.6%)
Communal land	43 (63.2%)	23 (41.8%)

[a] Multiple answers possible.
[b] Three goat farms practiced zero-grazing.

Table 2
Farmers' perceptions of the 103 studied farms raising a total of 123 sheep and goat flocks of the occurrence of endo- and ectoparasite occurrence (in % of flocks).

Parasite	Species					
	Sheep (n = 68 flocks)			Goats (n = 55 flocks)		
	Never	Occasionally	Often	Never	Occasionally	Often
Endoparasites						
Gastrointestinal nematodes	39.7	36.8	23.5	41.8	40.0	18.2
Liver flukes	66.2	20.6	13.2	82.3	7.3	5.5
Tapeworms	66.2	19.1	14.7	72.2	14.6	12.7
Coccidia (*Eimeria* spp.)	77.9	7.4	14.7	72.7	12.7	14.6
Lungworms	82.4	10.3	7.4	78.2	14.6	7.3
Ectoparasites						
Mites	55.9	35.3	8.8	72.7	23.6	3.6
Lice	89.7	8.8	1.5	76.4	14.6	9.1
Biting lice	92.7	4.4	3.0	81.8	9.1	9.1

is often a problem. More than two thirds of the farmers of both species perceived liver flukes, tapeworms, coccidia (*Eimeria* spp.) and lung worms as never occurring on their farm. Mites were perceived as the most frequent ectoparasites in sheep and lice in goats.

Ever before this study, feces samples for coprological analysis have only been collected in 16% of the sheep (11% once per year, 5% less than once per year) and 30% of the goat flocks (18% once per year, 10% less than once per year, 2% before and after anthelmintic treatment). The vast majority of the farms (sheep: 97%, goats: 91%) applied anthelmintic treatments. In sheep, anthelmintics were used once (32%) or twice per year (68%). Farmers that applied one treatment per year used it in spring (26%) or autumn (6%). In goats, 53% of the farms applied them once (25% in spring and 28% in autumn), 42% twice and 6% three times annually.

The choice of anthelmintics varied among farms but was dominated in both species by the macrocyclic lactone ivermectin (Table 3). This was followed by the benzimidazole albendazole at proportions of 20%. In the questionnaire seasonal differences of drugs used were not specified. In the majority of the sheep population drugs were administered subcutaneously (50.0%) followed by oral administration (33.3%), while the latter was the most frequent route in goats (46.9%). In general, the dosage was calculated by estimating the body weight of the individual animals. Only 21% of the sheep and 30% of the goat farmers provided data on the frequency of alternation of the anthelmintics. Less than 20% of the sheep and 26% of the goat farms indicated a change every one or two years. Eight percent of the sheep and goat farmers mentioned that the applied anthelmintic was not effective and another 5 and 11% of the sheep and goat farmers, respectively, that an insufficient effectiveness was noted in previous years. Only 7.8% of the sheep and 13.5% of the goat farmers used fecal analysis to examine the effectiveness of the treatment.

Table 3
Practices of anthelmintic usage for parasite control of the 103 studied farms raising a total of 123 sheep and goat flocks (in % of flocks).

Anthelmintic	Sheep (n = 68 flocks)	Goats (n = 55 flocks)
Benzimidazoles/probenzimidazoles		
Albendazole	20.5	20.0
Netobimin	7.7	–
Fenbendazole	–	10.0
Macrocyclic lactones		
Ivermectin	51.3	50.0
Eprinomectin	7.7	10.0
Other	12.8	10.0
Route of administration		
Oral	33.3	46.9
Subcutaneous	50.0	36.7
Intramuscular	6.4	–
Pour-on	11.0	16.3
Calculation of dosage		
Estimation of individual body weight	84.4	90.9
Average weight of adults	2.2	–
Average of the herd	13.3	9.1
Frequency of drug alternation		
Every year	12.9	12.0
Every 1–2 years	–	3.9
Every 2 years	6.5	10.0
Every 2–3 years	–	3.9
Every 5–7 years	1.6	–
No data	79.0	70.3
Effectiveness of anthelmintics		
Not effective	7.7	7.9
Partly effective	5.8	10.5
Effective	86.5	81.6
Applied measures to control effectiveness of anthelmintic treatments		
Weight gain	9.4	1.9
Hair coat	15.6	21.2
Faecal examination	7.8	13.5
No control	67.2	63.5

3.2. Prevalence and infection intensity of gastrointestinal helminths and coccidia

As presented in Table 4, more than 30% of the sheep < 6 months, 20% of the sheep from 7–12 months of age and 16% > 12 months were GIN-negative. In all three age classes, the proportion of samples classified as low (< 500 EPG) ranged between 49–62%. Around 7% of the samples in each age class were classified as high (> 1000 EPG). Specified by the different species identified by the FEC, *S. papillosus* was detected in 4% of the sheep < 6 months and less than 2% in the other age classes. Respective values for *Nematodirus* spp. ranged between 8% in animals < 6 months and > 12 months and 18% in those at an age of 7–12 months. The prevalence of *Trichuris* spp. ranged between 4% of the sheep < 6 months and 12% of the ones from 7 to 12 months of age. *D. dendriticum* was found in 8.2% of the sheep between 7–12 months of age and 2% in both other age classes, while tapeworms were found in around 13% in both groups below 12 months and 6.5% in adult sheep. In lambs, more than 20% of the samples were classified as medium (1800–6000 OPG) and another 22.5% as high (> 6000 OPG). In both other age classes less than 12% of the samples fell into these two categories of *Eimeria*-infections. Lungworms, as analysed at flock level, were found in 18.2% of the sheep flocks in autumn 2015 and 47–50% in both other seasons. Independent of the season, eggs of liver flukes were found in less than 2% of the flocks.

In goats, 15.9% of the samples collected from animals < 6 months were GIN-free, while 17.5 and 20.1% were classified as medium and high, respectively (Table 4). In goats with 7–12 months of age 11.6 and 16.8% of the samples fell within these two categories and 14.0 and 13.8% of the adult goats. *S. papillosus* was detected in 3.6% of the kids. The prevalence of *Nematodirus* spp. ranged between 10.9 and 18.0% in the different age classes. The highest prevalence of *Trichuris* spp. was found in the goats at an age of 7–12 months (3.4%). *D. dendriticum* was only found exceptionally. Tapeworms were identified in 18.5, 7.3 and 5.7% in goats < 6 months, 7–12 months and > 12 months, respectively. In kids, almost 30% of the samples were classified as medium in terms of *Eimeria*-infection and another 25% as high. Goats > 12 months showed *Eimeria*-infections that were classified as medium or high only at 15.9 and 2.8%. The prevalence of lungworms was 43.5% in autumn 2015 and more than 70% in both seasons of 2016. Liver flukes were not found in any of the goat flocks.

The interaction effect ($P < 0.01$) between species and age class for FEC and FOC is presented in Table 5. In detail, for neither of the age classes a difference between species was found ($P > 0.05$), while in

Table 4
Results of the fecal egg (expressed as eggs per gram, EPG) and oocyst (expressed as oocysts per gram, OPG) counts differentiated for the prevalence of gastrointestinal strongylid nematodes (GIN) (classified as negative, low, medium and high), *Strongyloides papillosus, Nematodirus* spp., *Trichuris* spp., tapeworms, *Dicrocoelium dendriticum* and *Eimeria* spp. (classified as negative, low, medium and high) separated by species and age class (expressed as % of samples).

	Sheep			Goat		
	< 6 months (n = 249)	7–12 months (n = 122)	> 12 months (n = 1327)	< 6 months (n = 189)	7–12 months (n = 232)	> 12 months (n = 1417)
	GIN					
Negative	31.7	20.5	15.9	15.9	23.3	22.6
Low (< 500 EPG)	48.6	54.9	62.3	46.6	48.3	49.7
Medium (500–1000 EPG)	12.9	17.2	14.0	17.5	11.6	14.0
High (> 1000 EPG)	6.8	7.4	7.8	20.1	16.8	13.8
	Strongyloides papillosus					
Positive	4.4	1.6	1.2	3.6	0	0.3
Negative	95.6	98.4	98.8	96.4	100	99.7
	Nematodirus spp.					
Positive	8.0	18.0	7.7	18.0	14.2	10.9
Negative	92.0	82.0	92.3	82.0	85.8	89.1
	Trichuris spp.					
Positive	3.6	12.3	7.0	0.0	3.4	1.7
Negative	96.4	87.7	93.0	100.0	96.6	98.3
	Dicrocoelium dendriticum					
Positive	2.0	8.2	2.3	0.0	0.0	0.3
Negative	98.0	91.8	97.7	100.0	100.0	99.7
	Tapeworms					
Positive	12.8	13.9	6.5	18.5	7.3	5.7
Negative	87.2	86.1	93.5	81.5	92.7	94.3
	Eimeria spp.					
Negative	9.6	36.1	28.2	2.1	6.5	8.7
Low (< 1800 OPG)	46.6	52.5	66.3	42.9	65.1	72.6
Medium (1800–6000 OPG)	21.3	4.9	4.5	29.6	21.1	15.9
High (> 6000 OPG)	22.5	6.6	1.1	25.4	7.3	2.8

sheep animals < 6 months had a lower FEC than animals of both other age classes ($P < 0.05$). In goats, however, age classes did not differ in FEC ($P > 0.05$). For FOC alike, species did not differ for any of the 3 age classes ($P > 0.05$). While in sheep lambs had a higher FOC than both other age classes, kids did not differ from goats with an age of from 7–12 months but only from those > 12 months ($P < 0.05$). In Table 6, the interaction effect between breed and age class ($P < 0.01$) for FEC is presented. A difference between age classes was only found for Tirolean mountain sheep, where animals < 6 months had a lower FEC than those > 12 months ($P < 0.05$). For animals > 12 months, Jura sheep had a lower FEC than Friesian milk sheep ($P < 0.05$). In goats, neither a difference between breeds of the same age class nor between age classes of the same breed were observed ($P > 0.05$).

Third-stage larvae identified in coprocultures were dominated by *Teladorsagia/Trichostrongylus* in both sheep (56.5 ± 24.5% (SD)) and goats (60.5 ± 25.8%) (Table 7). *Haemonchus* followed with around 30% in both species, but with a high variation between flocks. The other genera made up only a small proportion of third-stage larvae, though maxima at flock level of *Strongyloides* reached up to 87% in sheep and 42% in goats.

4. Discussion

The questionnaire provided an overview on the structure of small ruminant farming and with a large number of respondents can be considered as representative for sheep and goat farming in a mountainous region such as South Tyrol, Northern Italy. The structure, which is based on small-scale part-time managed farms, is comparable to other Alpine areas (Manfredi et al., 2010; Ringdorfer and Finotti, 2015; Zanzani et al., 2014). Characteristically a number of mountain sheep and goat breeds were prominent on the farms. While milk production is an important farming purpose in goats as in other regions of Northern Italy (Di Cerbo et al., 2010), sheep are raised for meat production. Typically, grazing is allowed from April/May until October/November, while animals usually are kept at privately owned pastures located at the farm location in spring and autumn and are moved to communal pastures at above 1500 m a.s.l. in summer. The use of communal grazing areas is more pronounced in sheep than in goats. On communal land, however, parasite control measures such as pasture management, e.g. drainage or exclusion of wet pasture areas or rotation of pastures, are complicated to apply. Also, strategies such as targeted (selective)

Table 5
Back-transformed least squares means and standard errors of fecal egg counts (FEC, expressed as eggs per gram) and fecal oocyst counts (FOC, expressed as oocysts per gram) of sheep and goats separated by age class and sex.

Age class	FEC		FOC	
	Sheep	Goats	Sheep	Goats
< 6 months	336^{Aa} ± 96 (n = 249)	799^{Aa} ± 122 (n = 189)	14120^{Aa} ± 2158 (n = 249)	7450^{Aa} ± 2219 (n = 189)
7–12 months	430^{Ab} ± 98 (n = 122)	498^{Aa} ± 98 (n = 232)	1248^{Ab} ± 2383 (n = 122)	1638^{Aa} ± 1967 (n = 232)
> 12 months	465^{Ab} ± 79 (n = 1327)	502^{Aa} ± 79 (n = 1417)	82^{Ab} ± 1737 (n = 1327)	612^{Ab} ± 1375 (n = 1417)

^{A,B}Least squares means with different uppercase superscripts indicate statistical difference of FEC or FOC between species within the same age class at $P < 0.05$.
^{a,b}Least squares means with different lowercase superscripts indicate statistical difference of FEC or FOC between age classes within the same species at $P < 0.05$.

Table 6
Back-transformed least-squares means and standard errors of fecal egg counts (FEC, expressed as eggs per gram) of sheep and goat breeds[a] separated by age class.

Breed	Age class		
	< 6 months	7–12 months	> 12 months
Sheep			
Tirolean mountain sheep	356^{Aa} ± 86 (n = 145)	402^{ABa} ± 108 (n = 70)	380^{Bab} ± 61 (n = 719)
Brown mountain sheep	265^{Aa} ± 165 (n = 48)	374^{Aa} ± 215 (n = 16)	481^{Aab} ± 104 (n = 193)
Jura sheep	380^{Aa} ± 183 (n = 27)	409^{Aa} ± 244 (n = 14)	303^{Aa} ± 123 (n = 155)
Villnösser sheep	665^{Aa} ± 324 (n = 7)	432^{Aa} ± 248 (n = 14)	493^{Aab} ± 163 (n = 53)
Friesian milk sheep	406^{Aa} ± 252 (n = 14)	431^{Aa} ± 317 (n = 8)	449^{Ab} ± 132 (n = 156)
Goats			
German fawn	$514^{n.s.}$ ± 274 (n = 9)	1847 ± 258 (n = 11)	486 ± 113 (n = 251)
Saanen goat	1571 ± 162 (n = 48)	670 ± 175 (n = 34)	595 ± 122 (n = 292)
Passeirer mountain goat	621 ± 95 (n = 119)	242 ± 88 (n = 186)	448 ± 69 (n = 689)

^{A,B} Least squares means with different uppercase superscripts indicate statistical difference of FEC or FOC between age classes within the same breed at $P < 0.05$. ^{a,b} Least squares means with different lowercase superscripts indicate statistical difference of FEC or FOC between breeds within the same age class at $P < 0.05$. $^{n.s}$Least squares means did neither differ at $P < 0.05$ between breeds nor between age classes of the same breed.

[a] Values are only presented for breeds with more than 50 individual samples on at least 5 farms.

Table 7
Third-stage strongylid larvae identified in coprocultures of sheep (n = 40) and goat (n = 31) flocks (expressed as mean percentage ± SD, range in brackets).

	Sheep	Goats
Teladorsagia/Trichostrongylus	56.5 ± 24.5 (0–100)	60.5 ± 25.8 (17–100)
Haemonchus	29.7 ± 24.8 (0–100)	30.0 ± 24.8 (0–68)
Oesophagostomum/Chabertia	2.1 ± 5.8 (0–29)	0.2 ± 1.0 (0–5)
Nematodirus	0.3 ± 0.9 (0–5)	0.1–0.6 (0–3)
Bonustomum	1.7 ± 4.0 (0–17)	1.3 ± 2.5 (0–11)
Cooperia	2.8 ± 5.7 (0–23)	4.2 ± 8.2 (0–33)
Strongyloides	7.4 ± 16.7 (0–87)	4.0 ± 9.3 (0–42)

treatments (Charlier et al., 2014) to combat parasitic infections and especially limit the spread of resistant parasites are of particular importance but not widely adopted by farmers using communal grazing land. The widely accepted strategy of selective treatment leaving part of the GIN population unexposed to anthelmintics in so-called “refugia” (Besier, 2012; Jack et al., 2017) in order to reduce the risk of the development of anthelmintic resistance is consequently far from being adopted in the studied region. Regulations on the use of anthelmintic treatments for animals from various farms that are grazing together during summer months on communal land are currently not in place. Results of Manfredi et al. (2010) undermine that goats which grazed at altitudes of 500–1000 m a.s.l. are found with a higher infection prevalence and mean abundance of GIN compared with animals that are kept indoors year-round.

Comparable to studies conducted in The Netherlands (Jack et al., 2017; Ploeger et al., 2016), GIN were perceived as the most important parasites by farmers. Despite, coprological analyses were only applied exceptionally. The very limited use of fecal analysis widely agrees with other studies (Pedreira et al., 2006; Zanzani et al., 2014). Even though indicated several sheep (14%) and goat (18%) farmers an insufficient effectiveness, feces samples were not the method of choice for efficiency control. This in addition to the fact that only a small proportion of farmers were able to provide data on the used anthelmintics undermines that the selection of the anthelmintic products is made by the veterinarians with limited influence of the farmers. However, data also point out that a regular change of the anthelmintic class is forced by part of the farmers. This emphasizes the need to strengthen the awareness for the risk of anthelmintic resistance development among farmers and veterinarians alike. This particularly holds true considering the anthelmintic resistance proven in goats of neighboring regions (Artho et al., 2007; Schoiswohl et al., 2017; Zanzani et al., 2014) and also given the extensive use of communal grazing areas at high altitudes during summer months.

Despite the fact that nearly all farmers applied one or two anthelmintic treatments per year, which is well in agreement with reports from other Italian studies (Manfredi et al., 2010; Zanzani et al., 2014), this is lower compared to other countries (Kupčinskas et al., 2016; Maingi et al., 1996; Ploeger et al., 2016). Given that sheep and goats from numerous, generally small-scale farms are commonly raised on communal alpine pasture areas during summer, facilitates the treatment of whole herds at the beginning of the pasture season.

The dominance of macrocyclic lactones contrasts findings of Zanzani et al. (2014), who reported that benzimidazoles and probenzimidazoles were applied on almost 90% of the 110 goat farms studied in Northern Italy. The prominent use of macrocyclic lactones in the region of the present study is partly due to the fact that these are also effective against ectoparasites, which were perceived as prevalent by a number of farmers. Though most studies report resistance against the older products of the latter mentioned group of anthelmintics (Čerňanská et al., 2006; Chartier et al., 1998; Kupčinskas et al., 2016), resistances against macrocyclic lactones (Čerňanská et al., 2006; Scheuerle et al., 2009) or even multiple classes of anthelmintics become more and more obvious (Kupčinskas et al., 2015; Lamb et al., 2017; Traversa et al., 2007; Van den Brom et al., 2013). To some degree an insufficient effectiveness was already mentioned by the sheep and goat farmers participating in this study alike. This again emphasizes the necessity for an improved management of endoparasitic infections focusing i) on the use of coprological analysis before anthelmintic treatments in order to adopt a targeted therapy and ii) drug alternation in the studied region. Nevertheless, the limited availability of registered anthelmintics, especially in goats, has to be stressed (Zanzani et al., 2014).

The proportion of 15–30% GIN-free animals of all age classes in both species points out that a regular drenching of all animals twice per year is not necessary and that strategies such as targeted (selective) treatment need more attention in the studied region. Overall, the GIN-prevalence of animals < 6 months is in the range reported in lambs by Idris et al. (2012) and in goats by Holm et al. (2014). Goats at an age of > 12 months were, however, found with a higher mean prevalence than those found in other studies from Northern Italy (Di Cerbo et al., 2010; Manfredi et al., 2010). To the authors’ knowledge there are no comparable studies from the whole region of Northern Italy in sheep available, yet. At species level, *S. papillosus* was found less often than *Nematodirus* spp., which contrasts the findings of Di Cerbo et al. (2010) and Manfredi et al. (2010) in goats from a neighboring region. With a maximum prevalence of 12.3% in sheep at an age of 7–12 months and below 4% in all age classes of goats, *Trichuris* spp. was identified less often than in both of the aforementioned studies. With regard to *D. dendriticum* previous reports are not available for neighboring regions, while prevalences were low in both species except sheep at an age of

7–12 months. In relation with the exceptional identification of large liver flukes, their prevalence in fecal samples was as low as the perception by the farmers. The low infection rates with liver flukes are thus comparable to those found in sheep in Germany (Kern et al., 2015). In contrast, tapeworms were found in both species, especially in animals within their first year of age, at a range as previously reported by Di Cerbo et al. (2010) and Manfredi et al. (2010). The high prevalence of tapeworms warrants further differentiation to species level in future studies to draw more detailed conclusions on their effective pathogenicity. For sheep and goats older than 1 year, the prevalence of *Eimeria* spp. was similar to the 92% reported by both Di Cerbo et al. (2010) and Manfredi et al. (2010). This clearly disagrees with the perceptions of the farmers surveyed with the questionnaire, though further differentiation to species level will be necessary to conclude on the effective pathogenicity, too. Alike, there are no data available for the prevalence of lungworms from sheep and goats of Northern Italy, which were however not further differentiated into *Muellerius/Protostrongylus* and *Dictyocaulus*. Similar to *Eimeria* spp., infection rates especially in goat farms are far above the farmers' perceptions. *Capillaria* spp. which were found at rates of 0.5% in goats by Di Cerbo et al. (2010) and Manfredi et al. (2010) were not recovered in the samples of the present study. Studies from other regions report much higher rates (Holm et al., 2014).

Compared to other studies from Northern Italian regions, infection intensity was higher than reported by Di Cerbo et al. (2010), but similar to that of Zanzani et al. (2014). Differences between sheep and goats might be due to divergent evolutionary processes (i.e. feeding behaviour and immune response) in responding to GIN infections (Hoste et al., 2010). Similar to findings of this study, Abebe et al. (2010) did not find any difference of FEC values between sheep and goats at an age of less compared with more than 1 year.

Confirming results of the present study, Heckendorn et al. (2017) under natural infestation as well as Werne et al. (2013) under artificial infestation did not find a difference in the GIN infection intensity between various sheep breeds in Switzerland. Similarly, lambs of four different species did not differ in FEC in the study of Idris et al. (2012). In the aforementioned studies conducted in Northern Italy, the breed was not considered. The large difference in *Eimeria* spp. infection intensity in young compared to adult sheep and goats emphasize the importance of these parasites for lambs and kids. It has to be stressed again that further differentiation to species level was not conducted.

The relative proportion of *Teladorsagia/Trichostrongylus* and *Haemonchus* in coprocultures widely agrees with findings of Idris et al. (2012). In goat farms of Northern Italy, Zanzani et al. (2014) recovered a similar distribution in coprocultures and identified the species of *T. circumcincta, T. colubriformis* and *H. contortus* at a prevalence of 73%, 34% and 46% in gastrointestinal tracts of the animals. Consequently, a high ability for overwintering under the specific mountain environmental conditions can be attributed to *Teladorsagia/Trichostrongylus.* Because habitats differ between the two most common species in temperate climates, namely *Trichostrongylus colubriformis* and *Teladorsagia circumcincta* (Gasnier et al., 1997), further differentiation is warranted in future studies in this region. Also, findings well agree regarding the very high variation of *Haemonchus* between flocks with some of them being free of this genera while in others this is the only one present. The small difference between sheep and goats reveal that both species share numerous GIN species (Hoste et al., 2010). At the same time, the most commonly found genera *Teladorsagia/Trichostrongylus* and *Haemonchus* are also the ones for which anthelmintic resistances are most severe (Borgsteede et al., 2007; Domke et al., 2011; Kupčinskas et al., 2015; Zanzani et al., 2014). Though, it should be mentioned that the conditions for culturing larvae in this study might have been sub-optimal for the two genera *Nematodirus* and *Strongyloides* when compared with the other genera.

5. Conclusion

This first report on endoparasitic infections of sheep and goats in the mountainous region of South Tyrol, Northern Italy reveals a high prevalence of endoparasites, especially GIN at a medium infection level, tapeworms and lungworms. Anthelmintics are regularly used, while fecal sampling for selective treatment only exceptionally. Therefore, parasite control measures should be optimized to reduce the risk for the development of anthelmintic resistance, which was already reported from neighboring regions.

Conflicts of interest

There are no conflicts of interest to declare.

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