Helminths and their management in Swiss Army horses: differences between riding horses and pack horses evidence the need of improvement

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Helmintenprophylaxe bei Schweizer Armeepferden: Unterschiede zwischen Reit- und Trainpferden weisen auf Verbesserungsbedarf hin

Das Management intestinaler Helminthen bei Pferden hat sowohl klinische als auch epidemiologische Relevanz, ebenso im Zusammenhang mit Anthelminthika-Resistenz. Die Schweizer Armee setzt Armee-eigene Reitpferde und privat gehaltene Trainpferde ein, welche für Diensteinsätze von bis zu 12 Wochen zusammengebracht werden. Wir haben die Haltungsbedingungen und das intestinale Helminthen-Management beider Gruppen mittels Fragebogen verglichen und haben Kotproben von 53 Reitpferden und 130 Tragpferden mittels kombiniertem Sedimentations-/Flotationsverfahren, McMaster Methode und Larvenkulturen analysiert.

Die Reitpferde zeigten lediglich Befall mit kleinen Strongyliden (Prävalenz: 60,4%), während die Tragpferde kleine Strongyliden (71,5%), *Parascaris* sp. (6,9%) und *Strongylus vulgaris* (1,5%) beherbergten. Regressionsmodelle, in welchen Kotproben-Befunde mit den Fragebogendaten kombiniert wurden, zeigten Zusammenhänge zwischen Haltungspraktiken und der Häufigkeit bestimmter Parasiten und führten zur Identifizierung von Risiko- und Schutzfaktoren. Weidemanagement, Hygiene und Entwurmungspraktiken variierten stark für die Tragpferde, während für die Reitpferde ein einheitliches Konzept vorhanden war. Dieses beinhaltete eine selektive Entwurmungsstrategie mit quantitativen Kotuntersuchungen auf Strongyliden vor Entwurmung (Schwellenwert von 200 Eiern pro Gramm Kot, EpG).

Entwurmungen basierend auf quantitativen Kotuntersuchungen, die wöchentliche Beseitigung von Kot auf der Weide, die Verabreichung von makrozyklischen Laktonen und eine regelmässige Entwurmung der Pferde erwiesen sich als Schutzfaktoren bezüglich des Schwellenwertes von 200 EpG für Strongyliden. Dem-

Summary

Intestinal helminth management in horses has both clinical and epidemiologic relevance, in additional association with anthelmintic resistance. The Swiss Army employs military owned riding horses and privately owned pack horses, which are brought together for service periods up to 12 weeks. We compared husbandry conditions and intestinal helminth management of both groups via questionnaire and analysed faecal samples of 53 riding horses and 130 pack horses using combined sedimentation/flotation, the McMaster method and larval cultures.

Riding horses only had cyathostomin infections (prevalence: 60,4%), while pack horses harboured cyathostomins (71,5%), *Parascaris* sp. (6,9%) and *Strongylus vulgaris* (1,5%). Regression models combining faecal sample results with questionnaire data unveiled correlations of husbandry practices with parasite frequencies identifying risk and protective factors. Pasture management, hygiene and deworming practices were highly variable for pack horses, while for riding horses there was an overall concept. This included a selective deworming strategy with faecal egg counts (FECs) of strongyles prior to deworming, applying a threshold of 200 eggs per gram of faeces (epg).

Anthelmintic treatments based on FECs, weekly faeces removal on pastures (pastures), the use of macrocyclic lactones and deworming horses regularly were identified as protective factors regarding the 200 epg threshold for strongyle eggs. Accordingly, the mean epg for strongyle eggs between the groups (111 and 539 in riding and pack horses, respectively) was significantly different ($p < 0{,}001$).

Overall, intestinal helminth management in pack horses showed room for improvement regarding pasture hygiene, the used anthelmintics and the frequency of deworming, from which all Swiss Army horses would benefit, as they share pastures during their entsprechend waren die durchschnittlichen Strongyliden-Eizahlen zwischen den zwei Gruppen (111 bei den Reitpferden und 539 bei den Tragpferden) signifikant unterschiedlich ($p < 0{,}001$).

Insgesamt wies das Endoparasitenmanagement bei den Tragpferden Verbesserungspotential auf bezüglich Weidehygiene, verwendeten Anthelminthika und Entwurmungsfrequenz. Hiervon würden alle Armeepferde profitieren, da sie während ihres Dienstes die Weiden teilen und somit das Risiko einer Parasiten-Übertragung besteht.

Schlüsselwörter: intestinale Nematoden, Militärequiden, *Parascaris* sp., Parasitenmanagement, *Strongylus vulgaris*, Risikofaktoren

service, therefore entailing the risk of parasite transmission.

Keywords: intestinal nematodes, military equids, *Parascaris* sp., parasite management, *Strongylus vulgaris*, risk factors

Introduction

Intestinal helminth management in horses has become an integral part of equine health management over the last years, challenging veterinarians and horse owners alike worldwide.[34] Regarding the relevance of helminth infections, several aspects need to be addressed. The tapeworm *Anoplocephala perfoliata,* large strongyles (mainly *Strongylus vulgaris*), and roundworms of the genus *Parascaris* are parasites known to cause colic in horses.[48] The latter are clinically relevant parasites especially in younger horses in which an infection may induce impaction of the small intestine.[35] *Parascaris* spp. are additionally of concern due to cases of anthelmintic resistance (AR).[48] In relation to prevalence and abundance, non-migratory small strongyles play the main role in horses in western Europe and most other regions of the world.[6, 37, 39] This group of parasites (also called cyathostomins and comprehending approximately 50 species)[26] is clinically relevant in case of larval cyathostominosis, induced by sudden eruption of encysted larvae into the intestinal lumen. This is a syndrome that occurs mostly seasonally in late winter or spring.[30] Although infrequent, the severity of this clinical manifestation combined with AR and spreading thereof in this group of parasites represent a major concern in equine healthcare.[19, 30, 60] Overall, the clinical relevance of intestinal parasitic infections, together with the increasing occurrence of AR in frequently occurring helminths, are significant for veterinarians as well as horse owners justifying the need of appropriate parasite control, management and surveillance.

Among the various formations in the Swiss Armed Forces, based on a militia-based military structure with conscription, there are also units that work with animals, i.e. horses and dogs. In particular, the Swiss Armed Forces work with two types of horse units, i.e. riding horses and pack horses. The group of riding horses consists of Swiss warmblood horses and is property of the Army. The second group, the pack horses (also called train horses), is composed of Freiberger horses and mules. Animals of this group are property of several horse owners, which provide the horses and mules for military service limited in time: they are employed in service periods of three to 12 weeks per year and are used to carry loads of supplies or moving wood out of forested areas.

The number of deployable pack horses varies approximately between 150 to 200. Most of these animals live with other horses, not used in the Army. There are no official requirements nor premising recommendations regarding parasite management in pack horses to be deployed in military service, and no information is available concerning husbandry and deworming practices conducted by the various horse traders. During their military service, pack horses that normally are dispersed on farms all over the country, come together and share stables and pastures, also with other Army horses. This might thus lead to contamination of the pastures and subsequent parasite transmission. Additionally, when returning to their home farms after military service, pack horses may import new parasites and contaminate pastures and stables and, potentially, compromise ongoing parasite management efforts on their farms.

The goal of this study was to gain insight on the intestinal helminth spectrum and prevalences in horses used in the Swiss Armed Forces and to identify potential for optimisation in the prevention and treatment of intestinal helminth infections to improve equine parasite management with appropriate recommendations.

Material and Methods

Study population

Pack horses and mules are owned by various horse traders, situated all over the country, although most of them are located in the Swiss Central Plateau. For simpler presentation purposes, mules will be included together with «pack horses», if not stated otherwise. Depending on the number of people that serve in the train units at a time, around 30 to 50 pack horses are deployed for the duration of approximately 12 weeks for recruit basic trainings, or for refresher training courses with a duration of three weeks. Pack horses in military service were sampled in the competence centre for veterinary services and army animals (KZVDAT) in Sand, Moosseedorf, near Bern. Animals not in military service during that time were sampled on their respective farms. Prior to sampling, an information letter was sent to the horse traders.

Riding horses are routinely used for equestrian training of recruits, soldiers, non-commissioned and commissioned officers. The Swiss Armed Forces owns approximately 60 riding horses: they are used until the age of 16 and then replaced by young warmbloods. Horses from this group were sampled in the KZVDAT in Sand or in the national equestrian centre in Bern.

In total, 183 equids were sampled: 130 pack horses, with 117 (90,0%) being Freiberger horses and 13 (10,0%) being mules, and 53 horses from the riding horse group. Overall, 119 were males (geldings) and 64 females. The median age was 8 years: 51 (27,9%) were 4–5 years old, 86 (47%) in the age category of 6–10 years, and 46 (25,1%) were 11–16 years old.

Faecal sample collection and analysis

Faecal samples were collected from September 2020 to October 2020, as well as from April 2021 to August 2021. They were collected in plastic bags immediately after defecation and stored at 3–6 °C, optimal for faeces intended for egg count analysis, until examination.[42] All samples were analysed by the sedimentation/flotation method using zinc chloride solution (1,45 g/cm^3).[10] For quantitative analyses, the McMaster technique was adopted,[10] with a detection limit of 50 eggs per gram (epg) of faeces.[49] Furthermore, larval cultures for differentiation of large and small strongyles were made and third stage larvae identified using key tables.[10]

Questionnaire

A questionnaire was designed for the participating pack horse owners and the national equestrian centre, including questions about the overall number of horses on the farm, presence of young animals (< 4 years) on the farm (yes/no), husbandry management (horses kept in single boxes/group paddocks) and pasture access (daily/2–6 times a week/fewer), alternating pastures (with horses from other farms/with horses within the farm/no alternating pastures), alternating with ruminants on the same pastures (yes/no), removal frequency of faeces in enclosures (multiple times per day/daily/fewer) and removal frequency of faeces on pasture (daily/multiple times a week/weekly/fewer), regular deworming (yes/no) and, accordingly, annual frequency of deworming (1x/2x/3x/4x/more), anthelmintic drugs used, as well as the implementation of faecal sample analysis prior to deworming (yes/no).

Data analysis

Prevalences and faecal egg counts (FECs) were evaluated applying descriptive statistics, for all samples and for the two groups (pack horses and riding horses) separately. Data from the questionnaire with information for husbandry and deworming management was also evaluated using descriptive statistics. A linear regression model (model 1) was used with strongyle (including small strongyles and *Strongylus vulgaris*) epg as the dependent variable to evaluate whether the value was influenced by factors related to husbandry and management. Independent variables included in this model were the number of horses on the farm, the presence of horses below 4 years of age on the farm, group paddocks vs. single boxes, alternating use of pastures, alternating pastures with ruminants, frequency of faeces removal on pasture, regular deworming, the usage of macrocyclic lactones, and faecal analysis prior to deworming. Regression coefficient B represented the change in excreted strongyle epg if the according independent variable was altered to its reference variable (e.g., horses kept in single boxes versus horses being kept in group paddocks). Logistic regression was used to determine risk and protective factors (independent variables) by combining data from the questionnaire with the results of faecal analyses, using backward-selection algorithms. Independent variables integrated in regression models were age, presence of horses below 4 years of age on farms, group paddocks vs. single boxes, alternating use of pastures, alternating pastures with ruminants, frequency of faeces removal on pasture, regular deworming, the usage of macrocyclic lactones and deworming based on FECs. Categorial independent variables were recoded into dummy variables to have binary outcomes (yes/no). Dependent variables, which had to be present in binary code, consisted of strongyle egg shedding (yes/no) (model 2), and strongyle egg shedding ≥ 200 epg (yes/no) (model 3). A model for *Parascaris* sp. egg shedding was evaluated but not included since the number of positive cases was too small for a reliable model.

All statistics were performed using SPSS® version 27. Values of $p \leq 0{,}05$ were considered significant.

Results

Questionnaire

A total of 62 questionnaires were sent out in writing, based on addresses delivered by the administrator for Swiss Army animals, by letter and/or email to owners of Swiss Army pack horses and to the veterinary team of the national equestrian centre in Bern. Overall, 53 complete questionnaires were returned (return rate: 85,5%).

Husbandry and pasture management

For the pack horse group, the number of horses on the farms ranged between one and 48 (median: 10, mean 17). Figure 1A illustrates the number of pack horses living on the respective farms (in percentages). Approximately two thirds of pack horses (97/130, 74,6%) were kept in single boxes, 25,4% (33/130) in group paddocks. In both, boxes and paddocks, faeces removal was performed multiple times per day in 68,5% (89/130) and daily in 31,5% (41/130) of the horses. Faeces removal on pastures was performed fewer than weekly (including never) in 64,6% (84/130), weekly in 13,1% (17/130), multiple times per week in 13,8% (18/130), and daily in 8,5% (11/130) of these animals (Figure 2). All pack horses had pasture access all year round, 70,0% (91/130) of them 2–6 times/ week and 30,0% (39/130) daily. In 37,7% (49/130) of the horses, alternate pastures within the farm (but none with horses from other farms) came into use, while for the remaining 62,3% (81/130), no form of rotational grazing system was adopted. In 35,4% (46/130) of the pack horse study population, an alternating pasture allocation with ruminants (cattle, sheep, or goats) was adopted.

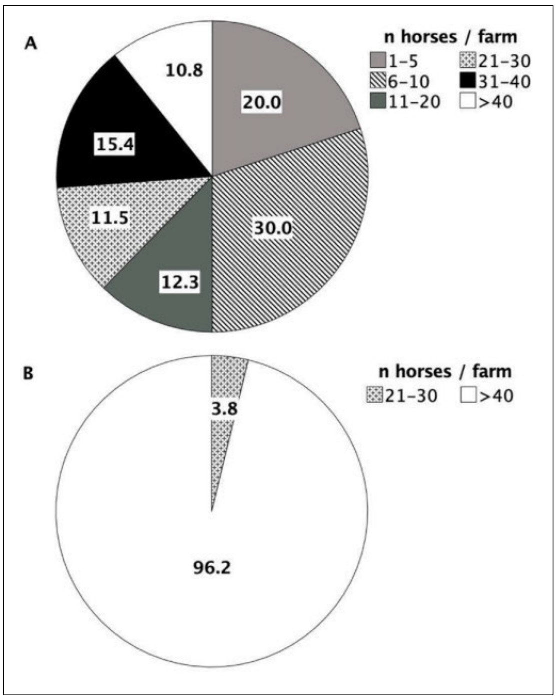

Figure 1: Group sizes (in percentages) of the study horses, for pack horses (n=130, Fig. 1A) and riding horses (n=53, Fig. 1B).

The riding horses were located either in Bern (n=51, kept with approx. 220 other horses on compound) or at the KZVDAT in Sand (n=2, together with approx. 25 horses on compound, Figure 1B). All of them were kept in single boxes. Faeces were removed from the boxes multiple times per day. The horses also had access to individual paddocks, and also in this group the horses had pasture access for 2–6 times a week, although only 6 months per year (April - September). Faeces removal on pastures was performed once a week. Only the two riding horses at the KZVDAT (3,8%) had alternate use of pastures with horses from the same compound, while all other horses (51/53, 96,2%) had their designated pasture and no rotational grazing system. There were no ruminants sharing the pasture with this group of horses.

Anthelmintic management

Anthelmintics applied to pack and riding horses are shown in Figure 3, in percentages and related to the total number of horses of each group separately.

The largest subset of pack horses (47,7%, 62/130) were given one single anthelmintic treatment/year in winter

Table 1: Prevalence of helminths identified by copromicroscopic methods in faeces of 183 horses of the Swiss Armed Forces (CI: Confidence Interval).

	Results obtained by sedimentation/flotation technique and larval culture								
	Pack horses (n=130)			Riding horses (n=53)			Total (n=183)		
	Positive (n)	%	95% CI	Positive (n)	%	95% CI	Positive (n)	%	95% CI
Small strongyles	93	71,5	63,0–79,1	32	60,4	46,0–73,5	125	68,3	61,0–75,0
*Strongylus vulgaris**	2	1,5	0,2–5,4	0	0,0	0,0–5,5	2	1,1	0,1–3,9
Parascaris sp.	9	6,9	3,2–12,7	0	0,0	0,0–5,5	9	4,9	2,3–9,1
	Results obtained by McMaster technique								
Small strongyles	84	64,6	55,8–72,8	25	47,2	33,3–61,4	109	59,6	52,1–66,7
Parascaris sp.	9	6,9	3,2–12,7	0	0,0	0,0–5,5	9	4,9	2,3–9,1

*positive strongyle samples were further analysed by larval culture

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(November or December). Two treatments per year were used in 23,8% (n=31) of all pack horses, the second treatment being also administered in winter, and in 0,8% (n=1) of these animals, owners opted for a treatment frequency of four times a year. In contrast, overall 27,7% (n=36) of the pack horses never received anthelmintic treatments in recent years. Selective anthelmintic treatment based on FECs prior to deworming was not adopted by pack horse owners. Anthelmintics in use were ivermectin (63,1%, 82/130), praziquantel (63,1%, 82/130, always in combination with ivermectin or moxidectin), pyrantel (16,2%, 21/130), moxidectin (10,0%, 13/130) and fenbendazole (8,5%, 11/130). In a few pack horses (6,9%, 9/130), owners also mentioned the use of alternative methods/substances such as plants or alcohol as an orally administered treatment.

Riding horses were regularly screened using FECs once a year in July. Horses with a strongyle epg of 200 or more (without differentiation) were dewormed, additionally to horses coproscopically positive for other parasite species (ascarids and tapeworms). The used anthelmintics were ivermectin (100%, 53/53), pyrantel (96,2%, 51/53), moxidectin (96,2%, 51/53), praziquantel (in 3,8%, 2/53 on a regular basis, because combined with ivermectin, for the rest only if indicated due to tapeworm infection), and fenbendazole (only in cases with diagnosed *Parascaris* sp. infections).

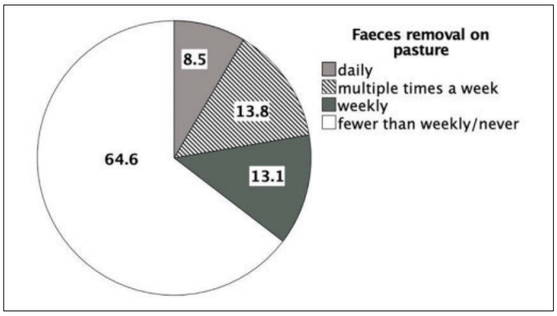

Figure 2: Frequency of faeces removal (in percentages) on pastures of 130 pack horses.

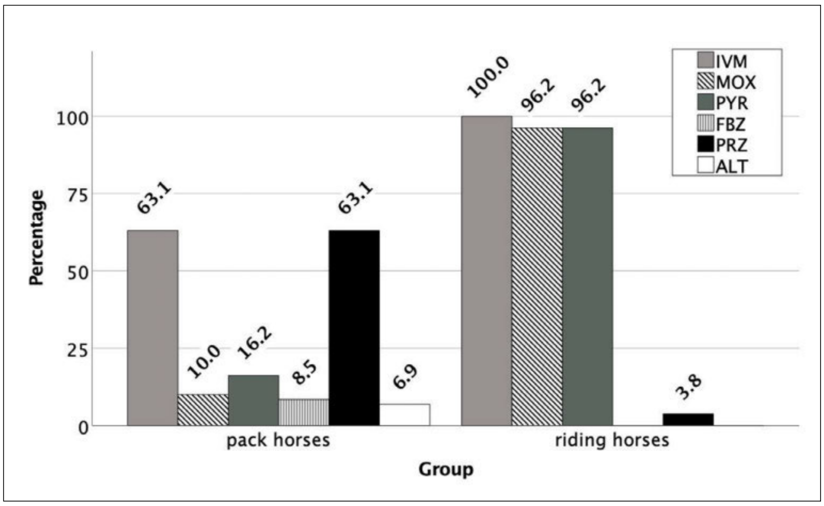

Figure 3: Anthelmintics applied to pack horses (n=130) and riding horses (n=53), in percentages; IVM: ivermectin, MOX: moxidectin, PYR: pyrantel, FBZ: fenbendazole, PRZ: praziquantel, ALT: alternative methods/substances.

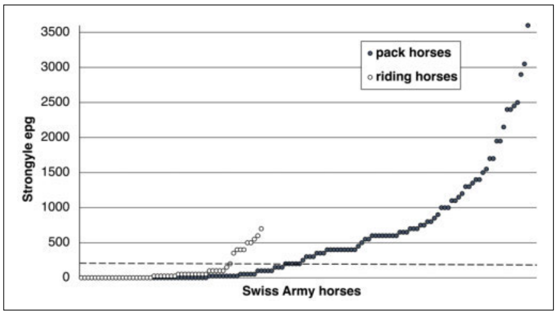

Figure 4: Individual strongyle faecal egg counts of all 183 horses from both groups, pack (n=130) and riding (n=53) horses. Each circle represents one horse. Strongyle egg numbers here include small strongyles and *Strongylus vulgaris*. The dotted line marks the 200 epg (eggs per gram of faeces).

Faecal examination

Of the 183 faecal samples analysed by the sedimentation/flotation technique, 127 (69,4%) were positive for parasite eggs. An overview on helminth prevalence is shown in Table 1. The most prevalent infection overall was with small strongyles (68,3%), followed by *Parascaris* sp. (4,9%). *Strongylus vulgaris*, identified through larval culture and differentiation of third-stage larvae, was present in overall 1,1% of the horses, and was the only large strongyle, detected in two pack horses. *Parascaris* sp. eggs were also present in pack horses only. No other parasite eggs or other stages were detected.

Based on results obtained with the sedimentation/flotation method, prevalence for strongyle infection (71,5%) and *Parascaris* spp. infection (6,9%) was higher in pack horses than in riding horses (60,4% and 0%, respectively). This difference was statistically significant ($p = 0{,}05$) for *Parascaris* sp..

Relying on results obtained by the McMaster method, overall 76 horses were negative for helminth egg detection, and prevalences were lower for small strongyle egg shedding, with 64,6% in pack horses and 47,2% in riding horses (overall: 59,6%). Prevalences for *Parascaris* sp. were the same as determined with the sedimentation/flotation method. FECs ≥ 200 epg for strongyle eggs were significantly more frequent in pack horses (54,6%) than in riding horses (18,9%) ($p = 0{,}036$). Also the mean epg for strongyle eggs was significantly higher in pack horses (539 epg) compared with riding horses (111 epg) ($p < 0{,}001$). Positive epgs in pack horses varied from 0–3600, epgs determined in riding horses ranged from 0–700 (Figure 4).

Combined statistical analysis of questionnaire and faecal examination data with regression models

The linear regression (model 1) identified several husbandry and management measures as variables significantly related to the strongyle epg (dependent variable) shed by the horses in this study ($F = 13{,}25$, $p < 0{,}001$) (Table 2). Based on regression coefficient B, higher strongyle egg shedding was therefore associated with macrocyclic lactones (ML) not being used for deworming (B = 585,0), with the presence of young horses < 4 years of age on the farm (B = 463,9), with faeces being removed from pastures less than weekly (B = 432,0), with deworming not based on FECs (B = 428,2), with alternating pasture usage between the horses on the farm (B = 319,3) and with horses being kept in group paddocks (B = 314,7). The remaining independent variables, being not statistically significant, were not listed in the table.

In addition, several logistic regression models were generated, and risk factors for each model, i.e. dependent variables, are listed in Table 3. For horses with faeces positive for strongyle eggs (model 2), no significant risk or protective factors could be detected. For the model with FECs ≥ 200 epg for strongyle eggs (model 3) as dependent variable (Chi-square (degrees of freedom: 4) = 47,8, $p < 0{,}001$), significant protective factors associated to husbandry and deworming practices were identified: the risk of horses having FECs ≥ 200 epg was significantly lower in horses kept in boxes and not on group paddocks, with weekly removal of faeces from pasture, with regular deworming (using any kind of anthelmintic regime at least once a year), using ML for deworming, and if deworming was based on FECs. The remaining analysed risk or protective factors for each model were not statistically significant and are not listed.

A model for *Parascaris* sp. egg shedding was not considered because of the limited number of positive horses. Although no statistical significance was determined, a commonality between *Parascaris* sp. positive horses was nonetheless apparent: in 8 out of the 9 positive horses (88,8 %) originating from 6 different farms, faeces were removed less than weekly from pastures.

Table 2: Statistical analysis of faecal examination data of 183 horses of the Swiss Armed Forces combined with questionnaire data in a linear regression model (model 1). Strongyle egg counts include both small strongyles and *Strongylus vulgaris*. Regression coefficient B in eggs per gram (epg) of faeces; y: years; CI: confidence interval; ML: macrocyclic lactones; FECs: faecal egg counts.

Dependent variable	Independent variable	Regression coefficient B	95 % CI	*p* value
Number of strongyle eggs shed (epg)	Horses < 4 y of age present on farm	463,9	255,9–672,0	< 0,001
	Horses kept in group paddocks	314,7	95,7–533,7	0,005
	Alternating pastures with other horses on the farm	319,3	104,9–533,8	0,004
	Less than weekly faeces removal on pasture	432,0	226,2–637,9	< 0,001
	Not using ML in the deworming process	585,0	339,5–830,5	< 0,001
	Deworming not based on FECs	428,2	226,1–630,3	< 0,001

Table 3: Significant risk and protective factors obtained with two different regression models (using different parameters of risk) regarding strongyle egg shedding, applied on faecal examination data of 183 horses of the Swiss Armed Forces combined with questionnaire data. CI: confidence interval; (S/F): sedimentation/flotation method; ML: macrocyclic lactones; FECs: faecal egg counts).

Parameter of risk	Risk factor/ protective factor	Regression coefficient B	95 % CI	*p* value
Faeces positive for strongyle eggs (S/F) (model 2)	–	–	–	–
FEC for strongyles ≥ 200 epg (model 3)	Horses kept in boxes	0,29	0,12–0,73	0,008
	Weekly faeces removal from pasture	0,27	0,13–0,58	< 0,001
	Regular* deworming	0,27	0,11–0,71	0,007
	Using ML as anthelmintic treatment	0,25	0,10–0,64	0,004
	Deworming based on FECs	0,19	0,09–0,42	< 0,001

*using any kind of anthelmintic treatment at least once a year

Discussion

This study presents data about husbandry and parasite management obtained by a questionnaire (return rate: 85,5 %), as well as results from faecal sample analyses from 183 horses used by the Swiss Armed Forces, i.e. 130 pack horses and 53 riding horses, and combines them to identify risk and protective factors for helminth infections.

The median number of horses on farms in the pack horse group was 10, which is higher than the mean number of horses per farm in Switzerland, being 5,6,[1] but lower than reported from large studies from Germany (26) [20] and Australia (63)[61] for example, considering overall 6'007 and 7'210 horses, respectively. Most of the pack horses were kept in single boxes, with a quarter of them (25,4 %) living in group paddocks, therefore being more frequently exposed to enclosures potentially contaminated with faeces from other horses. The riding horses in this study, instead, were housed on two large compounds with 25 and 220 animals each but were exclusively kept in single boxes and paddocks. Not having direct contact with other horses or their faeces may therefore contribute to explain the lower parasite prevalences compared to the pack horse group.

Pasture and stable hygiene are acquainted central aspects of parasite control in horses.[19] Comparing faeces removal management between the two horse groups, this procedure was performed at least daily in the main enclosure (box or paddock) of both pack and riding horses. On pastures, a broader variability of faeces removal frequency was observed. In the riding horse group, faeces were removed from pastures once a week. This frequency is recommended for reduction of infection pressure and is considered a pillar in the management of horse parasites,[19] recently also summarised in the horse guideline of ESCCAP (European Scientific Counsel Companion Animal Parasites).[51] In contrast, for most pack horses (64,6 %) faeces were removed less than weekly from pastures, including farms in which faeces were not removed at all. Accordingly, this also supports our results on higher helminth infections and prevalences in this group, due to infection pressure associated to survival of infectious stages on pastures.

Furthermore, in more than one third (37,7 %) of the animals of the pack horse group, pastures were alternately used by different horses kept within the farm, increasing the infection pressure due to potential egg contaminated faeces from more animals. On several of these farms, horses not connected to the Swiss Armed Forces and not being part of this study were present: they also may contribute to spread and transmission of helminth infections through common pastures.

Riding horses of the Swiss Armed Forces in the national equestrian centre in Bern had their designated pastures. These were usually not shared with other horses. During military service (mostly 3–12 weeks at a time) however, horses from both groups, pack and riding horses, did occasionally share the same pastures. This constant relocation of horses for military use differs from procedures in other countries where horses are constantly kept in military custody. For example, in Brazil,[9] Italy [52] and Portugal,[12] military horses are always kept on military compounds and their management is therefore more uniform. Thus, there is potential for transmission of helminth infections on Swiss military compounds, although faeces removal takes place once a week.

Ruminants using the same pasture alternately with horses has been shown to represent an effective measure for reducing infection pressure, since host-specificity is high in most nematodes.[19] In more than one third (35,4 %) of the pack horses, the owners followed this practice, mainly the ones who owned cattle or small ruminants. However, this was not identified as a protective factor in this study. This could be attributed to other risk factors overshadowing the potential benefits of this practice.

Importantly, pack horses also were reported to have year-round pasture access (one third daily, the other 2–6 times per week), in contrast to riding horses having pasture access only from April to September (and only 2–6 times per week). This again indicates lower infection pressure with helminths for riding horses compared to pack horses.

Regarding anthelmintic treatments, clear differences between the two groups were recorded. Approximately one third (27,7 %) of the pack horses never received any sort of anthelmintic treatment, although a «safety» treatment in winter in horses that have not been tested or treated all year is part of the recommended strategy of helminth management in horses in Switzerland.[19] This «safety» treatment is mainly intended to keep possible infections with *Strongylus vulgaris* under control. In fact, despite the limited number of cases, the two horses positive for *Strongylus vulgaris* in this study were part of the group of horses that had been left completely untreated. Almost half (47,7 %) of the pack horses were regularly treated once in winter, and 23,8 % twice a year, with one treatment being administered in winter, which would also cover the aforementioned safety treatment. One pack horse owner opted for four treatments a year, without FECs assessment, a procedure also in contrast with the indications to reducing annual treatments to one or two a year if not deemed necessary, aiming to slow down the development of AR.[24]

In fact, selective treatment based on FECs with defined epg thresholds has been shown to allow the reduction of the number of anthelmintic treatments and therefore to slow down further development of AR, in particular in Cyathostominae. This has been promoted for the last three decades:[16] by creating refugia of subpopulations of untreated small strongyles in horses and their environment, those nematodes are not exposed to selection pressure. The standard threshold epg value used in Switzerland referring to strongyles is 200,[19] and represents a widely used consensus, as stated by Nielsen et al.[41] These recommendations are based on studies showing that, when using a drug with maximum efficacy and if only horses with epg ≥ 200 are treated, the total egg shedding of a horse group is reduced by 96 %.[22] So, although FECs do not necessarily correlate with the actual worm burden in the individual horse,[37] selective deworming makes sense in terms of limiting the unnecessary use of anthelmintic drugs in horses that hardly contribute to contamination of pasture. Regarding small strongyle infections, the aim of a selective deworming strategy is not the complete eradication of this parasite from horse populations, but rather lowering infection pressure on pasture and worm burdens, while limiting the development of AR, accomplished by selectively treating «high shedders» and by regularly monitoring the efficacy of the employed anthelmintics.[19]

Pack horse owners did not adopt selective deworming with treatments based on FECs, and only one owner mentioned the intention to change to selective deworming the following year. Based on personal communications, in other pack horse owners the interest seemed to be very low, and they were not considering to change helminth management. In contrast, the riding horses, all kept in one of the two compounds for Army-owned horses, were all treated selectively, as the same team of veterinarians is responsible for parasite control for these horses. Among other Swiss horse owners using their animals for sport or leisure activities, 29 % were using a selective deworming approach based on FECs.[31] Apparently, the motivation in Swiss horse owners to adopt selective deworming is not high among Army pack horse owners. The reasons for that can only be speculated on, but are most likely related to economic reasons, with horses being more considered as a business and less part of a leisure activity. Importantly, many of the owners in this study stated that they were not aware of any health issues related to potential helminth infections; this would represent a valid argument for them whether to take measures or not. Clinical manifestations due to small strongyle infections are indeed of rare occurrence in Switzerland.[19] Nevertheless, hypobiotic encysted larvae can simultaneously initiate further development and cause extensive damage of the intestinal mucous membrane.[15] Larval cyathostominosis may result in an inflammatory enteropathy followed by weight loss and diarrhoea.[28, 30] Therefore, the clinical relevance of small strongyles is associated to the severity of this condition and their widespread occurrence.

Life-threatening conditions can also be induced by *Strongylus vulgaris*, causing intestinal infarction with resulting colic and peritonitis.[45] The threat associated to this nematode was ultimately the reason for widely used strategic deworming programs, also in Switzerland, in the second half of the 20th century.[19] Importantly, although diagnosed only in single cases, we identified *S. vulgaris* in Swiss Army pack horses, and one horse owner even stated having lost a horse due to *S. vulgaris* induced colic some years ago (personal communication).

The clinical relevance of *Parascaris* spp. is mainly connected to impaction colic caused by adult nematodes.[48] This parasite plays an important role in foals and yearlings,[35] however there are also *Parascaris* spp. cases described to be at the origin of colic in horses and equids older than a year.[53, 64] *Parascaris equorum* is known to be present in the general Swiss horse population.[19] Therefore, pack horse owners, especially the ones with young horses and foals on their farms, are recommended to maintain awareness for ascarid and *S. vulgaris* infections. Clinical manifestations due to these parasitic infections may be rare but this should not be a reason to neglect an effective and up to date deworming protocol.

Most pack horses (70,8 %) were treated with macrocyclic lactones (MLs) (60,8 % with ivermectin, 7,7 % with moxidectin and 2,3 % with both compounds). The use of moxidectin is specifically recommended in autumn/winter because of its efficacy against encysted larvae aiming at minimizing the risk of larval cyathostominosis.[30] Therefore, in addition to a substantial portion of pack horses not being anthelmintically treated at all, the compound proven to be the most effective against the most prevalent and critical nematode stages was not used very frequently in pack horses.

Virtually all riding horses were anthelmintically treated with a ML, i.e., ivermectin (100 %) and/or moxidectin (96,2 %), with the latter given to all but two riding horses. Routine deworming was primarily employed to control Cyathostominae infections. Among different anthelmintic groups, MLs were the ones with lowest AR prevalence worldwide, including Switzerland, specifically compared to AR against pyrimidines, i.e. pyrantel, or fenbendazole.[31, 38, 57] However, for MLs, shortened egg reappearance periods after treatments have been observed,[35] and only moxidectin has efficacy against encysted larvae.[19, 33] Given that, in this study, Cyathostominae were the only family of parasites found in the riding horse group, the use of MLs appears justified and logic.

Pyrantel was regularly used in 96,2% of riding horses, and also in 16,2% of the pack horses. The use of this anthelmintic could probably be omitted in many cases, since reduced efficacy of pyrantel against Cyathostominae has been reported in many studies,[7, 27, 32, 38, 56] including Switzerland,[31] particularly when comparing data with MLs. The widely adopted strategy against AR spreading, promoting the use of alternating between drugs, has not been scientifically proven useful,[22] and one study in fact confirmed that changing drug classes between anthelmintic treatments did not influence the development of AR.[58] This would additionally support the use of pyrantel being obsolete against Cyathostominae.[38]

Praziquantel is indicated against tapeworm infections, which are not frequently diagnosed in Switzerland (Hertzberg, personal communication). However, the sensitivity of standard faecal flotation is impaired for the detection of tapeworm infections,[54] so that prevalences for *Anoplocephala* spp. infections are potentially higher than what identified by routine faecal analyses. In this respect, the inclusion of praziquantel into winter deworming procedures to get rid of possibly undetected cestode infections may be indicated. Furthermore, praziquantel showed high efficacy against tapeworms in horses,[55] and AR has never been reported in equine cestodes.[47] Accordingly, the risk of AR development when using praziquantel without evidence of tapeworm infections is low. Praziquantel was used in 63,1% of pack horses. Yet, in riding horses, praziquantel is only used when *Anoplocephala* spp. infection is evident, which has not been the case over the course of this study. These Swiss Army riding horses did not have any apparent health related disadvantages from possibly undetected and untreated tapeworm infections.

Fenbendazole was employed in a limited number (8,5%) of pack horses, and not used in the riding horse group. Owners using fenbendazole mentioned the low price of this drug to be the main reason they used it (personal communication). In addition to the mentioned widespread AR of Cyathostominae against benzimidazoles,[7, 31, 56, 57] it was shown that the use of a five-day regimen with this drug led to a clear diminution of larvicidal efficacy compared to historical standards.[3] This five-day protocol was though not adopted by any of those pack horse owners, therefore probably further limiting the efficacy of fenbendazole. This example illustrates a certain lack of awareness among Swiss Army horse owners for AR development in equine helminths. Fenbendazole certainly has its place and benefits, e.g. against *Parascaris* spp. showing resistance against ML, premising correct dosages,[47] but is mostly useless against Cyathostominae. A limitation of the present study is given by the lack of specific efficacy data regarding anthelmintics used in Swiss Army horses, as it is generally recommended to monitor the efficacy of any anthelmintics used by performing faecal egg count reduction tests (FECRT).[20, 28]

Eventually, a small number of pack horses (6,9%) was given natural remedies as an alternative to deworming drugs. This included the use of different alcoholic liquors, grated carrots in large quantities and other plant-based regimens. Finding literature about the efficacy of such anthelmintic remedies is challenging. The use of grated carrots is described in ethnoveterinary medicines in Trinidad and British Columbia, Canada,[23] but no data about anthelmintic efficacy was given. A study from Italy showed that garlic, as an example of plant-based deworming, had no effect on egg shedding.[5] Other publications suggested alternative plant-based therapies against the threat of AR.[11] Further studies with bigger populations are required to evaluate if such plants or plant components might have the potential to be considered for the development of new anthelmintic drugs. With lacking scientific references whether alternative treatments may have significant effects on parasite infections in horses, these methods should be considered with scepticism. Although it is not necessarily possible to generalise, this shows the importance of consulting veterinary professionals and the need of staying up to date, in order to eliminate outdated or insufficient practices. This is even more important because the pack horses have regular contact for weeks with other horses, which might originate from stables with better anthelmintic management, and thus compromising those efforts. The import of horses harbouring drug resistant small strongyles or *Parascaris* spp. into an environment where they were not present before is reality and therefore horses should be monitored regularly.[36]

Small strongyles are ubiquitous in grazing equids around the world.[38] This is also reflected in the logistic regression model for presence of small strongyles (model 2) in this study, where no risk or protective factors could be determined. However, although not significant, we observed a trend of higher strongyles prevalence in samples from pack horses (71,5%) than from riding horses (60,4%), connected with differences in husbandry and deworming management, as mentioned above. Comparing internationally, prevalence in working horses in Romania was 70,3%,[6] while Army riding horses from Italy had a slightly lower prevalence (55%) for small strongyles.[52] In general horse population studies, i.e. from a 10-year study from Germany using nearly 3'500 samples, strongyle prevalence was 30,1%,[46] and among 2'301 Swiss horses only 19% were positive for strongyle eggs.[18] The results from this latter retrospective study were obtained using the McMaster method. In the present study we obtained lower prevalences (not statistically significant) with the McMaster method compared to the combined sedimentation/flotation method, with 64,6 % and 47,2 % prevalence in pack and riding horses, respectively. Still, these numbers were much higher compared to the above-mentioned strongyle prevalence of 19 %.[18] This, along with data obtained through the questionnaire, indicates that the Swiss Army horses represent a particular Swiss horse sub-population, although differences may be also due to other factors, such as age, that may act as possible confounders. Focusing on the comparison of the two groups of horses used in the Swiss Army, further differences were apparent. We observed a significant difference in the number of animals with FECs being ≥ 200 epg, i.e. 54,6 % vs. 18,9 % in pack and riding horses, respectively. In Swiss Army riding horses, this percentage was therefore closer to the approximately 10 % of Swiss horses with epg ≥ 200, obtained from a total of 12'689 examined horses.[29] Given that in Swiss Army riding horses selective deworming is applied, the significantly lower strongyle prevalence compared to the pack horse group is not surprising. Interestingly, deworming based on FECs has been identified as a protective factor for the dependent variable «epg ≥ 200» in the present study (model 3), with an odds ratio showing that horses not dewormed based on FECs have a 5,3 (1/0,19) times higher probability of having a FEC ≥ 200. There was also a highly significant difference between the mean strongyle epg count of the two groups, with the epg of the riding horse group being a) under the cut-off of 200 (111 epg) and b) close to the mean of 75 epg also observed in Swiss horses from the study with >12'000 horses.[29] In contrast, the mean epg in pack horses was clearly above the 200 epg threshold (539 epg).

The linear regression model indicated a correlation between high strongyle epg with several management and husbandry factors. First, strongyle epg was higher if horses younger than 4 years were present on the farm. The linear regression model also indicated higher epg values when the deworming strategy was not based on FECs. Interestingly, previous studies indicated that egg shedding levels remained consistent in individual horses,[2, 40, 62] and that single horses were in fact described to disproportionately contribute to pasture contamination, i.e. with 2 % of faecal samples being the source of 50 % of the excreted helminth eggs.[18] Furthermore, overall, young horses were also shown to have higher FECs, and this was suggested to be related to the lack of acquired immunity.[62] Therefore, grazing «high shedders» and young horses could lead to high contamination of the environment and thus, to increase the chance of transmitting parasitic helminth infections to new hosts, leading to FECs above treatment cut-off in these animals as well. FECs not only support the discrimination between animals to be treated or not, but they are also important as a tool to identify the «high shedders». The treatment of these latter animals prevents increasing risks of transmitting helminth infections via environmental contamination of pastures to other horses, which then may contribute to the onset of additional shedders. Furthermore, the amount of larval uptake has been linked to the chance of developing larval cyathostominosis.[289] Consequently, «high shedders» also contribute to a higher risk of the occurrence of this dangerous syndrome.

Associated with pasture contamination, still based on the linear regression model, FECs were higher in horses that were kept in group paddocks and that shared the same pastures with others, compared to horses held in single paddocks and having pastures always assigned to the same animals. Furthermore, Swiss Army horses living in group enclosures had a 3,45 (1/0,29) times higher risk of FECs above 200 epg vs. when being kept in single boxes in the logistic regression model (model 3), supporting the role of on-farm transmission of strongyle infections. In fact, while in Army service, horses from different farms with variable parasite management are brought together in one compound: this may lead to potential transfer of helminth infections between farms, including anthelmintic resistant isolates.

Based on the same logistic regression model, removing faeces less than weekly resulted in higher FECs. Very similar findings were previously observed in Germany and Austria.[2] Additionally, horses in the here presented study were 3,7 (1/0,27) times more likely to have epg ≥ 200 if faeces were removed less than weekly, i.e., weekly faeces removal was identified as a protective factor. All this confirms the previously stated importance of pasture hygiene for efficient parasite management in horses.[17, 19]

There was also a correlation between the currently adopted deworming practises for Swiss Army horses, the use of MLs, and strongyle egg shedding. Based on the logistic regression model, treating horses with ML resulted as a protective factor, with the probability of a strongyle epg ≥ 200 being 4,0 (1/0,25) times higher when MLs were not used. The linear model indicated the risk of higher epgs when not using MLs, as well. The usefulness of this anthelmintic class to reduce strongyle FECs in the study horses was therefore statistically confirmed.

Strongylus vulgaris was found in 1,5 % of pack horses. This data is comparable to an older Swiss publication, where *S. vulgaris* was found on two different horse farms.[31] The positive pack horses were both not receiving regular anthelmintic treatments and had not been coproscopically monitored previously for their strongyle spectrum. The presence of *S. vulgaris* would possibly not have been noticed on these farms until a horse may have presented corresponding clinical signs. Because selective deworming principally targets small strongyles, there are concerns that not treating horses with epg below 200 could lead to a re-emerging of *S. vulgaris*, which had become very rare over the past decades, as a consequence of frequent deworming.[41] While these concerns may be supported by findings from Denmark,[43] *S. vulgaris* in Switzerland was shown to be much less prevalent and not being about to re-emerge.[19] Importantly, the recommendations for strategic deworming treatments additionally include the examination of the strongyle spectrum. The two positive *S. vulgaris* findings in this study in pack horses confirmed the importance of differentiation.

Like *S. vulgaris*, also *Parascaris* sp. was only present in pack horses, with a group prevalence of 6,9 %. This nematode is mainly found in young horses, i.e. foals and yearlings:[10, 35] age predisposal has been associated to the development of immunity over time,[35] being at least partially independent from exposure to the parasite.[8] However, the relevance of older horses harbouring ascarids as a significant source of infection for young animals has also been described.[50] Accordingly, in our study, pack horses up to 12 years of age were positive for *Parascaris* sp. This finding correlated with other reports, e.g. from Burkina Faso,[50] Poland,[13] Ethiopia,[14] Cameroon [25] and Canada,[21] in which *Parascaris* was present also in older equids. In the studies from Africa and Canada, this was assumed to be due to compromised immunity associated with suboptimal nutritional status. The evaluation of nutrition was not part of the present study. Nevertheless, our findings could indicate that a certain lack of immune response might be present in Swiss Army pack horses, despite substantial differences in husbandry, climatic environment and other, compared to equids living in tropical Africa and Canada. It could also be argued that a possible reduced immunity might be connected to stress due to frequent relocations and strenuous physical exercise these horses undergo regularly. Further investigations into feeding practices and health status could identify additional risk factors. Importantly, the eggs of *Parascaris* spp. are highly resistant and can survive on pastures for years.[44] Again, this evidences the role of pasture hygiene, especially for frequently relocated animals, such as Army horses in Switzerland. Fitting with that is the fact that in 8 out of the 9 *Parascaris* sp. positive horses, although not statistically evaluable, faeces was removed from pastures less than weekly. Despite faeces removal on Army compound pastures being usually performed once a week, it is constantly carried out by different soldiers, and not always supervised. This leads to the assumption that those pastures may have been contaminated with *Parascaris* sp. eggs through infected pack horses. Therefore, Army horses returning from there could introduce this nematode to uninfected stables and pastures and the infection could successfully establish particularly in foals, but also in further adult horses.

Conclusion

Parasite management, including husbandry and deworming practices, was highly variable for Swiss Army horses. Irregularities and suboptimal practices in pack horses were reflected in much higher FECs for Cyathostominae and thus contributing to pasture contamination on Army compounds. They also harboured *Parascaris* sp., even in advanced age, and *Strongylus vulgaris*. This would not have been detected without this study, not only threatening these poorly monitored horses but also further horses that may share paddocks or pastures. The contrasting endoparasite situation in riding horses of the Army confirms that regular faecal sampling with selective deworming, combined with good pasture hygiene, is advantageous and recommendable. Since not many pack horse owners seem to be motivated to change their practices, a feasible way to obtain an improvement would involve sampling and deworming at the start of each period of military service. Overall, there clearly is room for improvement in endoparasite management of pack horses used in the Swiss Army. Only very recently, to support decisions regarding anthelmintic management in horses, a new tool for free usage has been provided by experts in pharmacology and parasitology of the Vetsuisse faculty in Zurich, which can be highly recommended as a source of information.[4]

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Declaration of Competing Interest

The authors declare no competing interests.

Ethics

Ethical standards were fulfilled according to national laws.

Helminths and their management in Swiss Army horses: differences between riding horses and pack horses evidence the need of improvement

N. Spieler, M. Schnyder

Les helminthes et leur gestion chez les chevaux de l'armée suisse: les différences entre les chevaux de selle et les chevaux de bât démontrent la nécessité d'une amélioration

La gestion des helminthes intestinaux chez les chevaux présente une importance clinique et épidémiologique, en association avec la résistance aux anthelminthiques. L'armée suisse emploie des chevaux de selle militaires et des chevaux de bât privés qui sont réunis pour des périodes de service allant jusqu'à 12 semaines. Nous avons comparé la détention animale et la gestion des helminthes intestinaux des deux groupes par le biais d'un questionnaire et analysé les échantillons fécaux de 53 chevaux de selle et 130 chevaux de bât en utilisant la sédimentation/flottation combinée, la méthode McMaster et les cultures larvaires. Les chevaux de selle ne présentaient que des infections à cyathostomes (prévalence: 60,4 %), tandis que les chevaux de bât hébergeaient des cyathostomes (71,5 %), *Parascaris* sp. (6,9 %) et *Strongylus vulgaris* (1,5 %). Des modèles de régression combinant les résultats des échantillons fécaux et les données du questionnaire ont révélé des corrélations entre les pratiques de détention animale et la fréquence des parasites, identifiant les facteurs de risque et de protection. La gestion des pâturages, l'hygiène et les pratiques en matière de vermifugation étaient très variables pour les chevaux de bât, tandis que pour les chevaux de selle, il existait un concept unitaire. Ceci comprenait stratégie de vermifugation sélective avec comptage des œufs fécaux (CEF) de strongles avant la vermifugation, en appliquant un seuil de 200 œufs par gramme de fèces (opg).

Les traitements anthelminthiques basés sur les CEF, l'enlèvement hebdomadaire des crottins sur le pâturage, l'utilisation de lactones macrocycliques et la vermifugation régulière des chevaux ont été identifiés comme des facteurs de protection concernant le seuil de 200 opg pour les œufs de strongles. En conséquence, l'iog moyen pour les œufs de strongles entre les groupes (111 et 539 chez les chevaux de selle et de bât, respectivement) était significativement différent ($p < 0,001$).

Globalement, la gestion des helminthes intestinaux chez les chevaux de bât a montré qu'il est possible d'améliorer l'hygiène des pâturages, le choix des anthelminthiques et la fréquence des vermifuges, ce dont tous les chevaux de l'armée suisse bénéficieraient, car ils partagent les pâturages pendant leur service, ce qui entraîne un risque de transmission des parasites.

Mots clés: nématodes intestinaux, équidés militaires, *Parascaris* sp., gestion des parasites, *Strongylus vulgaris*, facteurs de risque

Profilassi antielmintica nei cavalli dell'esercito svizzero: differenze tra cavalli da equitazione e da soma rivelano la necessità di un miglioramento

La gestione degli elminti intestinali nei cavalli ha una rilevanza sia clinica che epidemiologica, in associazione alla resistenza agli antielmintici. L'esercito svizzero impiega cavalli da equitazione di proprietà dell'esercito e cavalli da soma di proprietà privata, che vengono riuniti per periodi di servizio fino a 12 settimane. Abbiamo confrontato le condizioni d'allevamento e la gestione degli elminti intestinali di entrambi i gruppi tramite un questionario e abbiamo analizzato campioni fecali di 53 cavalli da equitazione e 130 cavalli da soma utilizzando la sedimentazione/flottazione combinata, il metodo McMaster e le colture larvali. I cavalli da equitazione avevano solo infezioni da cyathostomi (prevalenza: 60,4 %), mentre i cavalli da soma ospitavano cyathostomi (71,5 %), *Parascaris* sp. (6,9 %) e *Strongylus vulgaris* (1,5 %). I modelli di regressione che combinano i risultati dei campioni fecali con i dati del questionario hanno rivelato correlazioni tra le pratiche di allevamento animale e la frequenza dei parassiti, identificando fattori di rischio e di protezione. La gestione del pascolo, l'igiene e le pratiche di sverminazione sono risultate molto variabili tra i cavalli da soma, mentre per i cavalli da equitazione vi è stato un approccio più uniforme. Questo includeva una strategia di sverminazione selettiva con conta delle uova fecali (CEF) degli strongili prima della sverminazione, applicando una soglia di 200 uova per grammo di feci (upg).

I trattamenti antielmintici basati sulle CEF, la rimozione settimanale delle feci sul pascolo, l'uso di lattoni macrociclici e la sverminazione regolare dei cavalli sono stati identificati come fattori protettivi rispetto alla soglia di 200 upg per le uova di strongili. Di conseguenza, l'upg medio per le uova di strongili tra i gruppi (111 e 539 nei cavalli da equitazione e da soma, rispettivamente) era significativamente diverso ($p < 0,001$).

Nel complesso, lo studio ha mostrato che la gestione degli elminti intestinali nei cavalli da soma ha un potenziale di miglioramento per quanto riguarda l'igiene del pascolo, gli antielmintici utilizzati e la frequenza della sverminazione, di cui beneficerebbero tutti i cavalli dell'esercito svizzero, in quanto condividono i pascoli durante il loro servizio, comportando quindi il rischio di trasmissione dei parassiti.

Parole chiave: nematodi intestinali, equidi militari, *Parascaris* sp., gestione dei parassiti, *Strongylus vulgaris*, fattori di rischio

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