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Strongyle faecal egg counts in Swiss horses: A retrospective analysis after the introduction of a selective treatment strategy

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ABSTRACT

The standard parasite management of horses based on regular anthelmintic treatments, now practiced for decades has resulted in a worrying expansion of resistant helminth populations, which may considerably impair control on the farm level. The aim of the present study was to obtain a retrospective (year 2010 – 2016) nationwide analysis of faecal egg count (FEC) data from the Swiss adult horse population, related to horse age and geographic region. Thirteen labs provided a total of 16,387 FEC data of horses aged four to 39 years (average: 13.6 years). The annual number of performed FEC tests increased from 38 to 4,939 within the observation period. Independent of the annual sample size the yearly patterns of the FEC were very similar. Seventy-eight percent ($n = 12{,}840$) of the samples were negative and 90 % ($n = 14{,}720$) showed a FEC below 200 strongyle eggs per gram (EPG) of faeces. The annual mean strongyle FEC ranged between 60 and 88 EPG with a total mean of 75 EPG. Horses aged 4–7 years showed a significantly ($p < 0.00001$) higher mean FEC compared with the other age groups, differences were not significant among the older horses. Based on ZIP codes, samples were allocated by 70.0 %, 6.0 % and 0.2 % to the German-, French- and Italian-speaking regions of Switzerland, respectively. With 222 EPG the mean FEC in the French part of Switzerland was significantly higher ($p < 0.05$) than in the German-speaking region (60 EPG). Eggs of *Parascaris* spp., anoplocephalids and *Strongyloides westeri* were found in 0.36 %, 0.32 % and 0.01 % of the samples, respectively. Based on 3,813 questionnaire feedbacks from owners in 2017 covering a total of 12,689 horses, sixty-eight percent ($n = 8{,}476$) were dewormed without diagnosis, two percent ($n = 240$) were not dewormed at all, whereas for 30 % ($n = 3{,}721$) the selective anthelmintic treatment (SAT) concept was applied. The SAT implementation rate differed significantly ($p < 0.0005$) between regions, with 33 %, 20 % and 25 % for the German-, French- and Italian-speaking areas, respectively. The rate of horses spending 16–24 h on pasture per day was significantly higher in the French-speaking region compared to the German-speaking part of Switzerland ($p < 0.0001$). In addition, pasture

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hygiene was practiced at a significantly lower rate in the French-speaking part compared to the German- and Italian-speaking regions (both $p < 0.0001$). Overall, the shift towards the SAT-concept represents a very promising development with respect to mitigating the further spread of anthelmintic resistance.

1. Introduction

Gastrointestinal parasite infections are ubiquitous in horses, with cyathostomins being the most prevalent nematode group worldwide (Kuzmina et al., 2016; Leathwick et al., 2019; Woellner Santos et al., 2018). While young horses, not yet been able to acquire immunity are more susceptible to severe cyathostomin infections, potentially resulting in clinical disease, infections are generally associated with little pathogenicity in adult horses (Love et al., 1999; Matthews, 2014). The alarming increase of resistant cyathostomin and *Parascaris* spp. populations has considerably supported the necessity for a re-orientation in parasite management of adult horses in the last decade (Leathwick et al., 2019; Raza et al., 2019).

The first systematic survey in Switzerland, focussing on benzimidazoles (BZ)-resistant cyathostomins was performed two decades ago indicating that BZ-resistant cyathostomins were present in 49 % of 90 investigated stables (Meier & Hertzberg, 2005). These data and subsequent studies in pilot stables provided major stimuli for a re-orientation of helminth control in the Swiss adult horse population. Equine parasitologists and clinicians of the Vetsuisse Faculty in Zurich and Berne agreed on a consensus focusing on a concept of a selective control approach, based on individual faecal egg counts. In 2011 this concept (selective anthelmintic treatment, SAT) was officially recommended as the preferred control strategy for adult horses (≥ 4 years) in Switzerland (Hertzberg et al., 2014). In a stable entering such a monitoring program, four individual faecal egg counts (FEC) are performed between April and November. Strongyle egg counts of 200 or higher result in anthelmintic treatment. In addition, deworming is recommended if eggs of anoplocephalids, *Oxyuris equi* or *Parascaris* spp. are identified (independently of the egg numbers). Regular performance of larval cultures is highly recommended to identify presence of large (migrating) strongyles. Furthermore, essential elements of the strategy are the consequent implementation of faecal egg count reduction tests (FECRT), appropriate quarantine procedures for incoming horses, as well as effective hygiene measures on pasture and in the stable areas.

The aim of the present study was to perform a retrospective, nationwide analysis of FEC data of the Swiss adult horse population and their relation to region and pasture management.

2. Materials and methods

2.1. Analysis of FEC data

FEC data were obtained from Swiss labs offering quantitative coproscopical analyses for horses and led by a veterinarian. Initially, 16 laboratories were asked to participate in this study by providing their FEC data linked with the horses‘ age from the starting point of their service until end of 2016. All labs used the McMaster-technique with a sensitivity of 50 eggs per gram (EPG). Whenever the age or the confirmation of the adult status was not available, or the horse was younger than 4 years, the data were not included in the analysis. For all FEC data, which were linked with a ZIP code, an allocation to one of the main three linguistic regions in Switzerland (i.e., German-, French- or Italian-speaking region) was made (https://postleitzahlenschweiz.ch). Finally, 16,387 FEC results were included in the analysis. As all FEC data were analysed without identification of the donor horse, the possibility that single horses might have provided several samples for the analysis over time was not considered. Lastly, 13 labs were involved in the study. These were located in the northern and western part of Switzerland and covered both the German- and French-speaking linguistic region. No participating lab was situated in the Italian-speaking part of Switzerland. As the data arrived in various formats, their transfer to a Microsoft Excel file (Version 15.34) was necessary for primary analysis.

2.2. Statistical analysis of FEC data

FEC data were imported and analysed in R (Wang & Paul, 2019; R Core Team, 2023). A generalized linear model with the FEC modelled as a negative binomial distribution was used to analyse the variation in FEC with age, lab, region and year of sampling (glm.nb function from MASS package in R). For variables, in which there were multiple groups (e.g. month of sample collection) a post hoc analysis using the glht function and Tukey method from the multcomp package was run.

2.3. Online survey on horse husbandry conditions

The Swiss agricultural research center ‘Agroscope’, launched a nationwide survey in 2017 on the topic of horse keeping management. In total, 11,191 (24 %) out of 46,703 registered Swiss horse owners were randomly selected and contacted via e-mail. Three questions were relevant in the context of parasite management and were analysed as part of the present study. The major analysis was performed in Microsoft Excel (Version 15.34), calculating the frequencies of the different answer options and their allocation to one of the three language regions. For single analyses the Chi-Square test was used.

The first question focused on the deworming strategy, the second question on pasture hygiene measures. Both questions were in a multiple-choice format (single choice). For the deworming strategy, the following options were provided: (I) Preventive deworming (without diagnosis), (II) selective anthelmintic treatment, (III) no administration of a deworming treatment, (IV) other deworming strategy and (V) answer not known. As in Switzerland removing of manure in at least weekly intervals is recommended, the resp. answer options for the second question were grouped into:

- Sufficient pasture hygiene (Removing of faeces at least once a week)
- Insufficient pasture hygiene (No removal of faeces or in intervals longer than one week)

The third question focused on the quantification of the daily pasture hours during the grazing season. This question was in a combination style format: The weekly number of days horses have access to pasture was asked in a multiple-choice format, while the question about the duration of pasture time per day was in an open format (the participants were asked to fill in the average time per day the horse spend on pasture during the grazing season). The participants had the possibility to skip questions.

The results of the different cantons as well as the linguistic regions were compared with each other. The cantons ‘Bern (BE)’ and ‘Wallis (VS)’ are both bilingual and therefore part of the German and French linguistic region. As there was no further information from which part of the canton the survey data were collected, an allocation to the linguistic region was not possible for these cantons. As a compromise within the regional analysis the data of the canton Bern (86 % German language) were therefore counted towards the German linguistic region and the data of the canton Wallis (60 % French language) allocated to the French linguistic region. For a smaller German-speaking population in the canton Fribourg no compensation seemed eligible in the analysis and therefore the whole canton was allocated to the French-speaking region.

3. Results

3.1. FEC data analysis

Originally, 36,508 FEC data were obtained from 16 labs. Fifty-five percent of the dataset had to be excluded from the analysis due to missing age-specification of the samples ($n = 19{,}121$), or due to allocation to horses younger than four years ($n = 1{,}000$).

In total, 16,387 FEC data, analysed between 2010 and 2016 in 13 labs were included in the study.

The overall mean strongyle egg count was 75 EPG. Seventy-eight percent ($n = 12{,}840$) of the samples were negative in the quantitative analysis and 90 % of the samples ($n = 14{,}720$) were below 200 EPG (Fig. 1).

Before 2011, FEC were done in very small numbers only by two of the participating laboratories. There were more labs offering quantitative coproscopy in the following years, which contributed to the development of the diagnostic volume from 2012 onwards, when the number of FEC increased considerably (Fig. 2) from 826 to 4,939 in 2016. Independent of the annual sample size the yearly pattern of the FEC results, shown as negative and higher/lower than 200 EPG was very stable during the observation period (Fig. 2). Yearly EPG means varied in a small range between 60 and 88 (Fig. 2). Non significant p values ranged from $p = 0.675$ to $p = 0.998$.

The analysis by sampling month, comparing the FEC results of each calendar month against each other to elucidate potential seasonal differences revealed no statistical difference between any of the months: p values ranged from $p = 0.18$ to $p = 1$ (8,191 results).

For 12,483 samples (76.2 %) a regional identification based on the ZIP code was possible. These were allocated to the German-, French- and Italian-speaking region of Switzerland by 70.0 %, 6.0 % and 0.2 % resp. Mean FEC values varied among the three linguistic regions (Fig. 3).

The difference between the German- and the French-speaking part was highly significant ($p = 1.07\text{e-}12$) and was also responsible for a considerable variation between the rates of samples inducing treatment (FEC $\geq$ 200 EPG) which were calculated as 8.5 % for the German- vs. 27.8 % for the French-speaking region. Due to the small data volume from the Italian part, the statistical analysis did not include this region. Data of the three labs providing results from both the German and the French region, showed a similar region-specific ratio of the mean strongyle FEC (German: 61, French: 168) as for the regions in total. The lab-specific strongyle FEC are shown in Fig. 4.

Statistical FEC analysis comparing the FEC results between the labs led to 78 comparisons and revealed 7 pairs with significantly different results between labs, p values ranging between $p = 0.0435$ and $p < 0.0001$. All these 7 pairs included at least one lab examining samples from the French-speaking part of Switzerland.

FEC analysis with respect to the horse age was performed on the basis of 8,191 samples. The age ranged between four and 39 years, the average being 13.6 years. Horses in the category of 4–7 years showed a significantly ($p < 0.00001$) higher mean EPG compared with the other groups (Fig. 5). Differences between the other groups were not significant ($p > 0.05$).

No significant correlation could be found between the mean FEC and the calendar month of sampling.

The participating labs were asked if larval cultures for strongyle differentiation were performed on a regular basis. Only 3 out of the 13 sites performed larval cultures during the study period and the results were not included in the data sets provided by the labs.

3.1.1. Non-strongyle GI helminths

Information about other GI helminths was available for 15,721 McMaster results. Eggs of *Parascaris* spp., anoplocephalids and *Strongyloides westeri* were found in 0.36 % ($n = 57$), 0.32 % ($n = 51$) and 0.01 % ($n = 2$) of the samples, respectively.

3.2. Questionnaire data analysis

This part of the study was performed independently of the FEC analysis described before. In total 3,813 questionnaires were filled, covering 12,689 horses, corresponding with a return rate of 34 %. This represented approximately 11 % of the total Swiss horse population, in 2017 (https://tierstatistik.identitas.ch/de/equids-CH.html).

3.2.1. Deworming strategy

Data were available for 12,541 horses. 67.5 % ($n = 8{,}476$) of the horses were dewormed without any previous diagnosis, whereas in 29.6 % ($n = 3{,}721$) of the horses the SAT concept was applied. Two percent ($n = 240$) of the surveyed horses were not dewormed at all.

The implementation rate of the SAT-concept showed distinct regional differences. The rates in the German-, French- and Italian-speaking areas were 33 %, 20 % and 25 %, respectively. Differences were highly significant among all linguistic regions ($p < 0.0005$) Fig. 6.

3.2.2. Pasture hygiene

As indicated in Table 1, fifty-three percent of the horses grazed on pasture sufficiently cleared from manure (i.e. at least once a week).

Wherever the location of the horses included in the study was available, an additional analysis of the data related to the linguistic regions of Switzerland was carried out ($n = 11{,}728$). In the French-speaking part of Switzerland pasture hygiene was practiced at a significantly lower rate compared to the German- and Italian-speaking regions (both $p < 0.0001$).

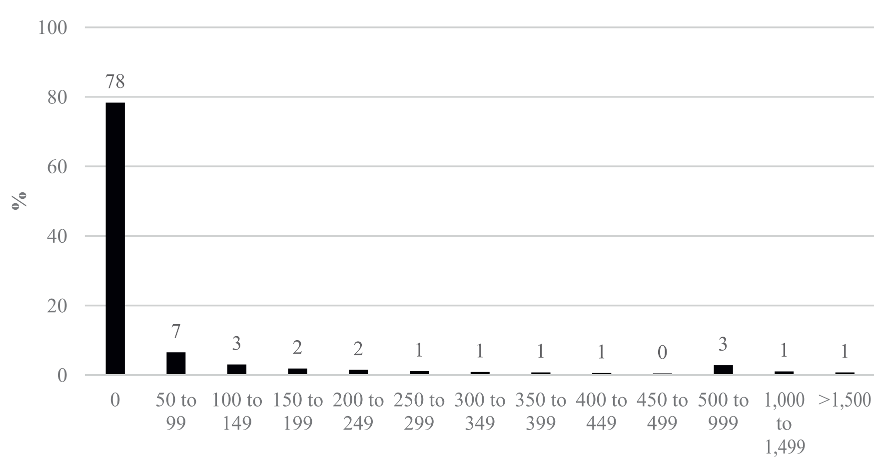

Fig. 1. Distribution of strongyle FEC in 16,387 samples from adult horses analysed between 2010 and 2016.

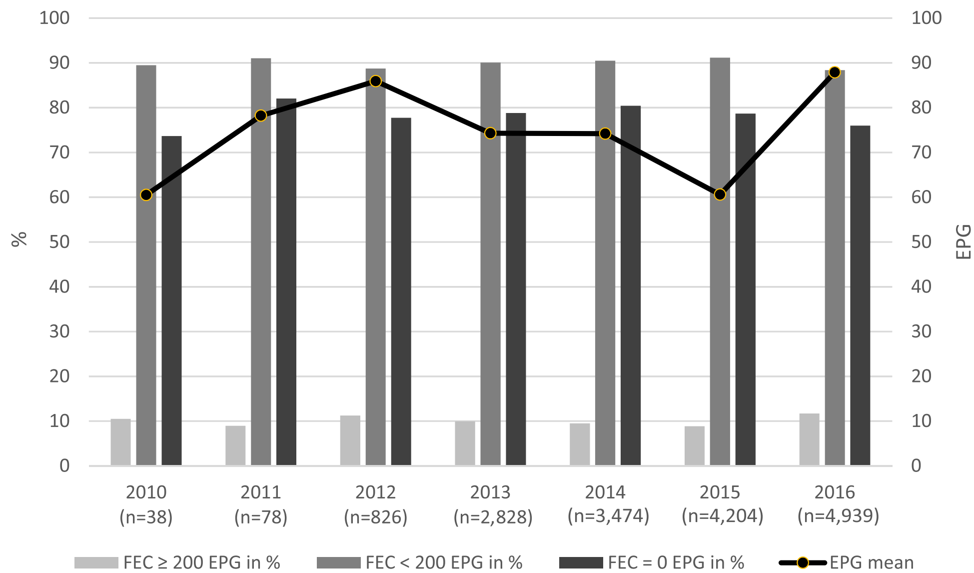

Fig. 2. Distribution of the yearly strongyle FECs and yearly EPG means in 16,387 investigated horse samples.

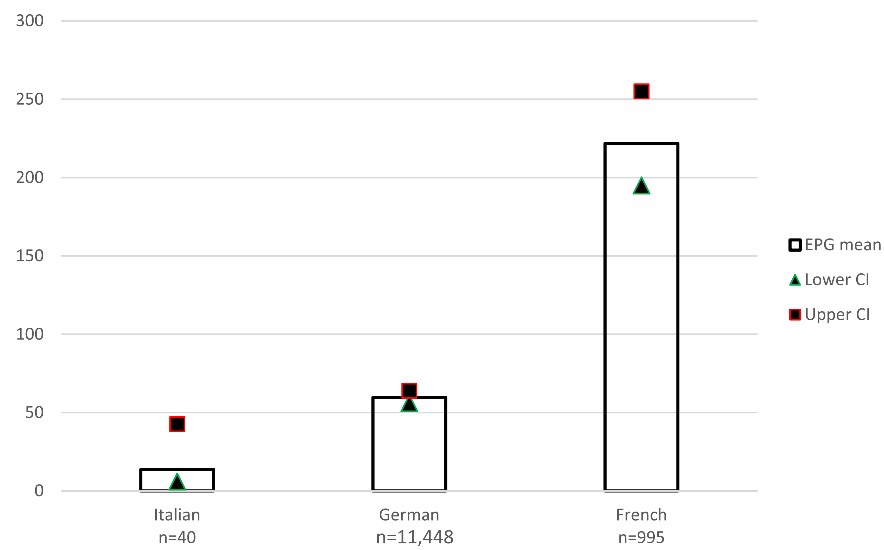

Fig. 3. Mean strongyle FEC of horse samples obtained from the different linguistic regions in Switzerland. The squares and triangles indicate the 95 % Confidence Intervals.

3.2.3. *Time on pasture*

The weekly number of days horses spent on pasture during the grazing season (May – October) in the different linguistic regions is shown in Table 2.

Participants that chose 'daily pasture usage' ($n = 3,450$) were asked about the daily hours horses spent on pasture. Horses in the Western part of Switzerland spend more time on pasture compared with the other two regions (Table 3). The rate of horses spending more than 16 h on pasture daily is significantly higher in the French-speaking part compared to the German-speaking part ($p < 0.0001$).

4. Discussion

The concept of SAT was recommended to equine practitioners and horse owners in Switzerland in September 2011 as the preferred strategy for helminth control in adult horses. This approach was based on results of pilot studies reflecting an imbalance between the frequency of routine anthelmintic treatments and the magnitude of cyathostomin egg-shedding, and as a consequence of worldwide reports about the increasing significance of anthelmintic resistance (Matthews, 2014; Peregrine et al., 2014).

Before 2011 only a very limited number of faecal examinations were performed in Swiss horses, whereas after the new strategy has been released the demand for faecal diagnostics by horse owners and veterinarians increased substantially. We therefore can assume that the vast majority of the FEC data analysed in this study derived from regular monitoring, as recommended, and that only a small rate of FEC data was affected by recent deworming.

As all major Swiss veterinary labs agreed to participate in this study, we can estimate that in the core period 2015 and 2016 the collected data represented the majority of the total FEC performed in equines on the national level and therefore the obtained annual data volume may serve as a good indicator for the total equine diagnostic volume in Switzerland. However, only the data sets which included the age of the horses were used for the analysis and therefore were used in this study (about 50 % of the total available data set). It is assumed that due to the overall large data volume this reduction did not bias the analysis on the national level.

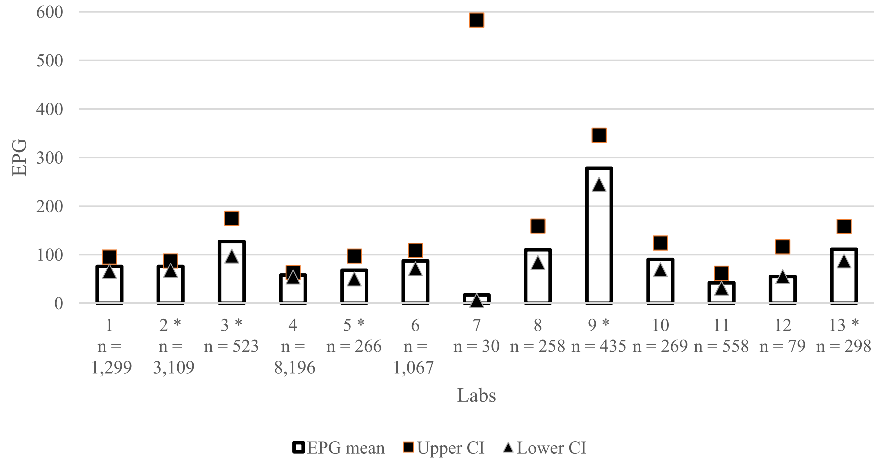

Fig. 4. Mean strongyle FEC analysed on lab level. The squares and triangles indicate the 95 % Confidence Intervals. (*indicates labs partly or entirely analysing samples from the French-speaking region of Switzerland.).

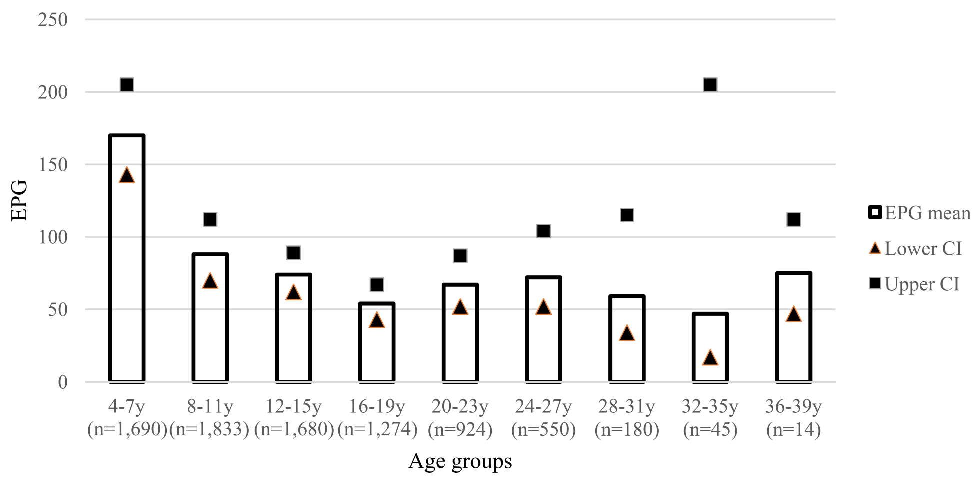

Fig. 5. Mean strongyle FEC calculated for age groups. The square and triangle indicate 95 % Confidence Intervals.

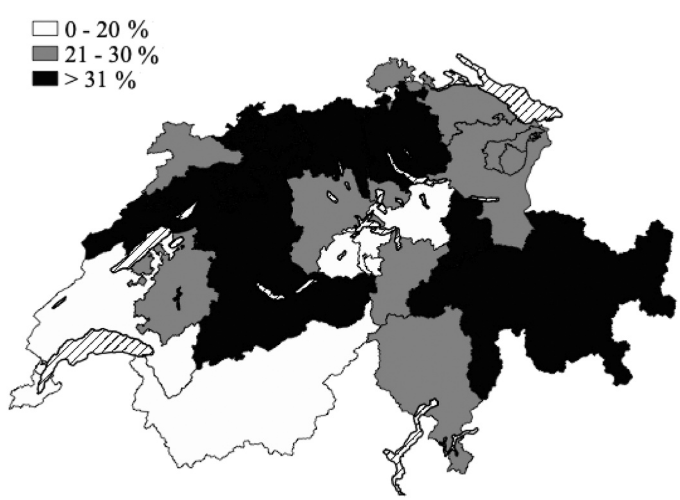

Fig. 6. Implementation rate of the SAT concept in the different Swiss cantons.

Independent of the annual data volume, the within-year distribution of the FEC data showed a remarkable stability. This is indicated by the rate of samples exhibiting a FEC below 50 (range over years: 74–82 %) and the rate of samples below 200 EPG (range over years: 88–91 %).

Table 1
Pasture hygiene measures in the German, French and Italian speaking region of Switzerland. (11,728 horses) as well as the percentage representing the situation in Switzerland in total.

Pasture hygiene measures	*German (n=8,727)*	*French (n=2,801)*	*Italian (n=200)*	*Switzerland (total) (n=12,101)*
At least once per week	57.0 %	37.8 %	56.5 %	53.0 %
At least once per month	11.7 %	11.9 %	16.5 %	12.0 %
At least once per year	3.2 %	4.9 %	4.0 %	3.0 %
Harrowing of the pasture	18.2 %	25.4 %	19.0 %	20.0 %
No pasture hygiene	9.9 %	20.1 %	4.0 %	12.0 %

Table 2
Contact of horses with pasture per week in the German, French and Italian speaking region of Switzerland (7,365 horses).

Pasture turnout	German (n = 5,521)	French (n = 1,703)	Italian (n = 141)
Daily	89.5 %	94.5 %	98.6 %
4–6 days per week	9.0 %	5.1 %	0.7 %
2–3 days per week	1.2 %	0.3 %	0.7 %
<2 days per week	0.3 %	0.1 %	0.0 %

Table 3
Daily grazing hours of horses in the German, French and Italian speaking region of Switzerland (3,450 horses).

Time spend on pasture per 24 h	German (n = 2,665)	French (n = 760)	Italian (n = 25)
≤5 h	35.4 %	20.1 %	28.0 %
>5–10 h	30.5 %	27.2 %	52.0 %
>10–15 h	21.7 %	33.6 %	20.0 %
≥16 h	12.4 %	19.1 %	0.0 %

Furthermore, between 2010 and 2016 the annual mean strongyle egg count fluctuated within a close range of 61 and 88 EPG, with no significant differences present between years. This indicates that what has been shown about the stability of FEC from single horses (Becher et al., 2010; Lester et al., 2018; Nielsen et al., 2014; Scheuerle et al., 2016; Wood et al., 2013) also holds true on a large population level. Thus, the pattern of egg-shedding seems to be very constant and also independent from the time of the year and from the increasing number of horses included in the selective control strategy every year. Furthermore, it is interesting that the mean FEC level was apparently not influenced by the change towards the SAT strategy occurring within the study period.

It is well known that cyathostomin populations are overdispersed among their hosts (Galvani, 2003; Scheuerle et al., 2016). Various studies have examined the phenomenon of the low and high shedders (Lester et al., 2018; Nielsen et al., 2006a). Kaplan & Nielsen (2010) formulated the so-called 20/80 rule, meaning that approximately 20 % of the horses contribute to 80 % of the total cyathostomin egg output. The present data exhibit an even more pronounced distribution, with only 7.5 % of the faecal samples accounting for 80 % of the total cyathostomin egg output over the entire study period. The reasons why certain horses are clearly more prone to higher FECs than others are still not fully understood, but it is likely that the individual genetic background has an important impact (Gold et al., 2019; Kornas et al., 2015). In a recent study from Eastern Germany, comprising 484 horses from 48 stables, FEC higher than 200 EPG were measured in 28 % of the faecal samples (Jürgenschellert et al., 2022), in contrast to 9 % in the present study. One reason for the overall low cyathostomin FEC level could be related with the fact that a large portion of the Swiss horses are only kept on pasture for a few hours daily (Hertzberg, 2016), which is in contrast to other European countries such as the UK, Germany, Sweden, Ireland and Norway (Elghryani et al., 2019; Fritzen et al., 2010; Hartmann et al., 2017; Nielsen et al., 2006a; Relf et al., 2012). As many Swiss horses are kept in suburban areas with limited availability of pasture, preserved forage is estimated to contribute to the roughage intake to a large extent also during the grazing season. In addition, more than 50 % of the horses covered by the here presented questionnaire survey grazed on pastures which are cleared from faeces at least on a weekly basis. Taken together, conditions which largely mitigate the risk of significant cyathostomin infections are prevailing in the majority of the stables.

The mean FEC showed a significant non-linear decrease with age, which is in accordance with observations in other studies (Francisco et al., 2009; Kornas et al., 2010; Larsen et al., 2002; Osterman Lind et al., 1999). The Swiss SAT guidelines exclude horses younger than 4 years, therefore this age group was not considered within this study. The youngest age group comprised horses from 4 to 7 years, which showed a significantly higher mean FEC in comparison with the older horses. This may indicate that immunoprotection against cyathostomin infection is still not fully matured in 4-year-old horses. In Switzerland the husbandry conditions change for a large portion of young horses when they are between 3 and 4 years old: they leave the raising stables, where they were kept in groups of mixed ages after weaning. Within this age group the mean FEC declines continuously (data not shown) and it is most likely that at least in the 4–5-year old horses egg shedding still originates from cyathostomin infections obtained in the raising units. These infections can persist due to insufficient efficacy of all anthelmintic drugs against the mucosal larval stages. After leaving the raising units the young horses mostly live among adults, which nowadays are kept group-wise in the majority of Swiss stables. Under these conditions, the young horses profit from the low pasture infectivity induced by the adults and it is therefore justified that they are integrated in the selective control concept, where they will receive more anthelmintic treatments when showing elevated FEC repeatedly. Specific FEC data of horses, 4–7 years old, should be collected in other countries as well, to enable region-specific conclusions on the type of parasite management in this age group. Little, non-significant variation of the mean FEC was observed between the age groups of horses older than 7 years, instead. One element of the study was to compare the FEC data between the participating labs to detect potential lab-specific effects and regional differences. Comparison of the data was permissible, as the same McMaster-technique was used in all labs and most of them had participated in practical courses at the Vetsuisse Faculty Zurich. Significant differences in these pair-wise comparisons were only detected in seven cases. In all of these comparisons one of the resp. labs covered the French-speaking (western) part of the country. Significantly higher FECs originating from the French-speaking part of Switzerland were also evident within each of the data sets of the three larger labs examining samples from both regions, excluding a lab-specific bias. When comparing the total cyathostomin FEC data by region, a significant 3.7 fold higher level was present for horses from the French- compared with the German-speaking part. This difference was also reflected by the rate of samples indicating treatment (FEC ≥ 200 EPG): 8.5 % in the German- vs. 27.8 % in the French-speaking regions. The latter results are in the same range with those recently reported in a study of five horse farms in Western Switzerland and France (34.7 %) (Roelfstra et al., 2020). As only a small data volume was available for the Italian-speaking region (canton Ticino), no statistical analysis was done here. The lower availability of data from this region is most likely influenced by the situation that many samples are preferably sent across the border to Italian labs, where diagnostics are done at lower costs.

The results of the questionnaire study, performed independently from the lab survey, served as a valuable supplement for interpretation of the regional FEC data. Both parts of the study are based on large, region-specific data volumes. However, as both surveys were anonymous, we have no indication to what extent the responders of the questionnaire and the owners providing the faecal samples were overlapping. To consider this potential weakness, interpretation was limited to the description of compatibility of the FEC results and pasture management data specific for the investigated geographical regions.

The results of the questionnaire survey indicated that the number of daily hours horses spent on pasture is significantly higher in the French-speaking part than in the rest of the country which is most likely due to the higher availability of grazing areas. The extended pasture contact increases the exposure to infective cyathostomin larvae and results in higher FECs (Fritzen et al., 2010; Relf et al., 2013). Furthermore, regional differences were also obvious in the implementation of pasture hygiene measures. In the German-speaking part 57 % of the horses live in a pasture environment which is cleared from faeces at least once a week, whereas the corresponding rate in the French-speaking part is significantly lower (38 %). Data published 15 years ago in the German-speaking region indicated a rate of pasture cleaning of 33 % (Meier & Hertzberg, 2005). This remarkable increase reflects a change of the owners' and horse keepers' attitude within the recent years, which is associated with the re-orientation towards SAT. Several studies have shown the beneficial effect of pasture hygiene on lowering the infection pressure with cyathostomins in horses (Corbett et al., 2014; Herd, 1986; Matthee & McGeoch, 2004). Therefore, in combination with the longer exposure to pasture, this factor likely contributed substantially to the higher FEC measured in the French-speaking part of the country. A potential additional factor, being much more difficult to quantify, is the different age composition of the horse population within the country. Recently, it has been shown in pony stables that adult horses having pasture contact with young ponies exhibit significantly higher FECs compared with adult horses that graze without contact to young ponies (Gysin et al., 2020). The highest foal birth-rate in Switzerland was documented in the western part of the country, especially in the canton Jura (https://tierstatistik.identitas.ch/de/equids-birthCanton.html). This may result in a higher exposure to contaminated pastures for adult horses in that region. The regional differences in the mean FEC observed in a small country like Switzerland are somewhat reflecting the situation also existing between different European regions. Considerably higher mean strongyle egg counts compared with the eastern part of Switzerland are reported from horses in Denmark (Nielsen, 2012) and Poland (Kornas et al., 2010) and it is likely that the same mechanisms described in the present study also contribute to the different scenarios observed in these more remote regions.

Also the overall frequency of annual treatments within the SAT concept in Switzerland is similar to what is reported from Germany and Austria (Becher et al., 2018; Simoneit et al., 2018).

The possibility of a re-emergence of large strongyles is a frequently expressed argument directed against the selective treatment approach. In Denmark – one of the countries in which the SAT-concept was introduced by governmental legislation (Nielsen et al., 2006b) – researchers have observed higher individual and on-farm prevalences of *S. vulgaris* in stables where horses had been treated selectively compared with stables performing standard treatments not based on FEC (Nielsen et al., 2012). However, the concept of selective treatments practised in the investigated Danish stables seems to be largely different from what is practiced in Switzerland and what is actually propagated in the European ESCCAP guidelines (ESCCAP, 2019). For example, in Switzerland and the ESCCAP guidelines it is recommended to perform one annual anthelmintic treatment (macrocyclic lactone plus praziquantel) per horse independent from the diagnostic results in order to mitigate re-emergence of large strongyles and to interrupt the development of anoplocephalids. In a more recent study, Swedish researchers found that stables treating on the basis of FEC and performing regular diagnostics for *S. vulgaris* had a significantly lower prevalence for this parasite compared to stables performing routine treatments or treating selectively without specific diagnostics (Tydén et al., 2019). The results underline the importance of combining selective anthelmintic treatments in horses with diagnostic measures for detecting large strongyles. In Switzerland we have no evidence of a higher prevalence of large strongyles since the introduction of the SAT concept in 2011. Compared to the situation in Denmark (12 % at farm and 64 % at individual level) (Nielsen et al., 2012) and Sweden (28 % and 61 %, respectively) (Tydén et al., 2019) a clearly lower prevalence of *S. vulgaris* (3 % at farm level) was recorded in Switzerland already before the re-orientation of the control concept towards selective treatments (Meier & Hertzberg, 2005). Data from one of the participating labs indicate that *S. vulgaris* was absent during an 8-year monitoring program covering more than 1,500 horses (data not shown). However, it is evident that coprocultures for strongyle larval differentiation are insufficiently requested by the horse community and further efforts are necessary to raise more awareness that this technique or alternative available molecular tools are an essential component of the SAT concept. Furthermore, innovative solutions based on a fixed combination of FEC and larval cultures on the stable level, as they are offered by one of the participating labs, can ensure that all horses are checked for patent *S. vulgaris* infection at least on a yearly basis. Unlike the situation in other countries, it is suggested that the SAT concept should not (further) be implemented in stables in which *S. vulgaris* has been detected, until proof of eradication (ESCCAP, 2019; Hertzberg, 2016).

Ten of the participating labs provided information regarding the prevalence of non-strongylid helminths: *Parascaris* spp., *Strongyloides westeri* and tapeworms occurred with a very low incidence of less than 1 %, indicating that these parasites play a minor role in the adult horse population in Switzerland, which is in agreement with a recent study from Germany (Jürgenschellert et al., 2022). Based on the current level of implementation, we assume that the shift towards SAT resulted in a considerable reduction of anthelmintic drug usage on the national level. Due to the low FEC especially in the eastern part of the country the average number of yearly treatments within the SAT-concept will be close to one. Such a scenario will most likely mitigate the further development of resistant cyathostomin populations (Matthee & McGeoch, 2004; Von Samson-Himmelstjerna, 2012).

5. Conclusions

This study provides support that thorough and profound education of the horse community can successfully modify attitudes and change behaviour, creating a more stable situation with respect to development of resistant cyathostomin populations. The advantage of a small country like Switzerland is that a limited number of key-players in the equine sector can find a consensus and agree on a uniform message. This message must be scientifically sound and readily understandable to be adopted by the horse community. In order to assure the quality standards, it will be essential that experienced veterinarians take a central position in the dissemination of correct information and parasite management, coordinating appropriate diagnostic procedures and assure that all relevant components of a monitoring program are fulfilled. The concept of SAT presented within this study has been developed for the epidemiological situation in Switzerland and will require reassessment and adaptation when used in different epidemiological settings.

CRediT authorship contribution statement

H. Hertzberg: Conceptualization, Writing – Review & Editing, Supervision. **S. Lüthin**: Conceptualization, Investigation, Data Curation, Writing – Original Draft, Visualization. **P. Torgerson**: Formal analysis, Visualization. **M. Schnyder**: Writing – Review & Editing. **A. Zollinger**: Resources. **W. Basso**: Resources. **M. Bisig**: Resources. **N. Caspari**: Resources. **V. Eng**: Resources. **C. F. Frey**: Resources. **F. Grimm**: Resources. **P. Igel**: Resources. **S. Lüthi**: Resources. **W. Regli**'†: Resources. **L. Roelfstra**: Resources. **M. Rosskopf**: Resources. **B. Steiner**: Resources. **M. Stöckli**: Resources. **D. Waidyasekera**: Resources. **P. Waldmeier**: Resources.

Declaration of Competing Interest

No COI to declare.

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