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REVIEW ARTICLE

Sustainable control of cyathostomin infections in practice

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Summary

Cyathostomins are the most prevalent helminths in horses and are found in nearly all grazing groups. These parasites have been shown to exhibit widespread anthelmintic resistance and can cause clinical disease, so they are a growing concern. The emergence of large numbers of larval stages from the large intestinal wall can cause larval cyathostominosis, a severe colitis that has a case fatality rate of around 50% in referral hospitals. Effective control of cyathostomins requires a combination of excellent paddock management, testing to identify horses that require treatment, and strategic treatments of high-risk individuals where testing does not provide useful information. Faecal egg count (FEC) tests are valuable tools for reducing anthelmintic treatments. These tests assess strongyle egg levels in dung, and because many horses have low egg shedding, testing can substantially reduce the amount of treatments administered by identifying such low egg-shedders. However, egg shedding does not correlate with cyathostomin counts in individuals, meaning that some horses may exhibit negative/low FEC results despite having substantial worm burdens, particularly of encysted larval stages. To mitigate the risk of harbouring pathogenic encysted larval burdens, it was previously recommended that horses in northern temperate regions receive an annual larvicidal treatment in late autumn or winter. This blanket approach to treatment likely increased selection for anthelmintic resistance. To avoid further selection for resistance in these regions, cyathostomin treatments in autumn/winter should be guided by risk assessment. High-risk horses should receive a cyathostomin larvicidal treatment, while low-risk horses may not require treatment. For those concerned about withholding anthelmintic treatment, a cyathostomin-specific ELISA (Small Redworm Blood Test, Austin Davis Biologics) can confirm if a horse has a low burden that does not necessitate treatment. This review provides a background to cyathostomins and their control, together with considerations for integrating this ELISA into sustainable control approaches to manage these important infections of horses.

KEYWORDS
horse, control, cyathostomins, diagnosis, ELISA, faecal egg counts

INTRODUCTION

Due to their high prevalence, potential to cause disease, and ability to develop anthelmintic resistance, cyathostomins are regarded as the primary parasitic pathogens of horses in northern temperate zones, such as the UK (Love, 1992; Matthews, 2014). This nematode group comprises 51 species (Lichtenfels et al., 1998); however, typically, horses are infected with 5–10 common species, often with low burdens of rarer species. Cyathostomins infect most grazing horses, with prevalence rates frequently approaching

100%. A systematic review (Bellaw & Nielsen, 2020) indicated consistent species prevalence and infection intensity patterns globally, with *Cylicocyclus nassatus*, *Cyathostomum catinatum* and *Cylicostephanus longibursatus* being the most common species documented. Surveys over several decades also demonstrate that species prevalence patterns have not changed significantly despite extensive use of broad-spectrum anthelmintics for over 40 years (Bellaw & Nielsen, 2020).

Key factors that impact the effective management of cyathostomins include the complexity of their life cycle, the range of burdens in individuals (from hundreds to several million worms) and high levels of anthelmintic resistance. Resistance has been commonly reported to fenbendazole and pyrantel, with emerging resistance to macrocyclic lactones (Matthews, 2014; Nielsen, 2022). Since no new chemical classes are coming to market in the foreseeable future, these findings underscore the urgent need to reduce anthelmintic use. In practice, balancing the requirement to treat individuals to prevent disease and the need to avoid anthelmintic overuse can be challenging. For this reason, evidence-based approaches to cyathostomin control need to be deployed. These include the use of assessments to inform parasite risk levels, applying excellent paddock hygiene measures and using testing to guide treatment decisions. This ensures that, while striving to preserve the effectiveness of anthelmintics, treatment is not withheld from horses at risk of parasite-associated disease.

THE CYATHOSTOMIN LIFE CYCLE AND ITS IMPACT ON TREATMENT AND CONTROL RECOMMENDATIONS

When horses ingest cyathostomins, the third stage larvae (L3) exsheath in the tubular glands of the large intestine and become encapsulated in the caecum and colon (Poynter, 1967). Here, they develop through several encysted stages (early L3 (EL3), late L3 (LL3) and developing fourth-stage larvae, DL4). The encysted larvae can persist for extended periods (Smith, 1976) before L4 emerge into the lumen and mature to adult worms that release eggs. The duration from ingestion of L3 to egg excretion in faeces (the prepatent period) can range from 2 months (Tiunov, 1953) to more than 2 years (Smith, 1976). This timeframe is primarily dictated by the encystment phase, and it is believed that the immune response is a key factor influencing the level and duration of encystment (Klei & Chapman, 1999). Some horses can harbour millions of encysted larvae, particularly during winter in northern temperate regions (Mathieson, 1964; Ogbourne, 1975, 1976; Reinemeyer et al., 1986). Having large burdens of these stages puts horses at risk of larval cyathostominosis, a severe colitis caused by the emergence of L4 from the intestinal wall (Giles et al., 1985; Walshe et al., 2021). To address this, it has been previously suggested to administer larvicidal anthelmintics to eliminate the majority of larval stages and adults to reduce disease risk, as well as the number of parasites that survive to the next season (Rendle et al., 2019). In the UK, anthelmintics with licensed efficacy against encysted stages include moxidectin or a five-day fenbendazole regimen; however, due to high levels of resistance to benzimidazoles (Matthews, 2014; Nielsen, 2022), moxidectin has commonly been recommended for this treatment. Giving anthelmintics prophylactically to all horses is likely to apply substantial selection for anthelmintic resistance.

In the luminal phase, studies show a decline in adult cyathostomin populations in spring as larvae emerge (Mathieson, 1964; Ogbourne, 1975, 1976). These new adult populations likely come from L3 ingested the previous year. This cycle results in adult burdens and egg excretion being higher in spring and summer in northern temperate regions (Duncan, 1974; Wood et al., 2013). The fastest development from egg to L3 stage also occurs from late spring to early autumn in these regions (Duncan, 1974; Mfitilodze & Hutchinson, 1987; Ramsey et al., 2004), making treatments to reduce egg contamination crucial during these times. To minimise contamination during this epidemiologically important phase, treatments should be based on faecal egg count (FEC) analysis to reduce anthelmintic use and mitigate the risk of resistance.

WHAT FACTORS AFFECT LARVAL DEVELOPMENT AND THEIR EMERGENCE FROM THE INTESTINAL MUCOSA?

Addressing the encysted mucosal phase is key in managing cyathostomin infections. Effective control of these stages necessitates an understanding of the circumstances involved in larval development. Factors that promote encystment include repeated exposure to infection (Love & Duncan, 1992; Murphy & Love, 1997), an individual's immune status (Chapman et al., 2002), the horse's age (Klei & Chapman, 1999) and, possibly, the environmental conditions (i.e. chilling) to which L3 are exposed before infection (Murphy & Love, 1997). As indicated above, in the natural life cycle in northern temperate regions, L4 emergence occurs in late winter/early spring and may be associated with declines in adult populations in the lumen (Ogbourne, 1975). In heavily infected individuals, synchronous larval emergence can occur, especially when there is a sudden loss of luminal stages, such as after an adulticidal anthelmintic treatment (Reid et al., 1995). It has been proposed that treatment-induced adult worm death may eliminate a negative feedback mechanism from luminal worms, allowing encysted larvae to resume development and emerge simultaneously (Smith, 1976). The emergence of many larvae can lead to disease. It is therefore important to avoid the build-up of encysted larval burdens in susceptible horses. This can be achieved by applying excellent paddock management and using effective larvicidal anthelmintics in horses deemed at risk.

The pathogenesis of larval cyathostominosis remains poorly understood; affected horses frequently display substantial burdens and intestinal inflammation (Ogbourne, 1975). Accurate sampling of both luminal contents and intestinal wall material for

worm counting presents considerable challenges to ascertain the cyathostomin burden that causes disease. This is underpinned by the scarcity of studies documenting cyathostomin counts in affected horses. The one experimental study available (Murphy & Love, 1997) indicated that administering 3.15–3.9 million cyathostomin L3 in repeated oral infections resulted in extremely variable burdens in the infected horses, with subsequent burdens ranging from 10,000's to >1000,000 worms, with larval establishment rates ranging from 0.94% to 39.7%. In this study, two of the six infected ponies developed signs of larval cyathostominosis (weight loss and diarrhoea). At post mortem examination, several weeks after the development of clinical signs, the encysted larval burdens in these horses were estimated as 1,245,100 (plus 7000 luminal cyathostomins) and only 10,500 (plus 0 luminal cyathostomins), underscoring the complexity of predicting disease risk in these infections.

It is important to also consider that cyathostomins have been associated with other clinical conditions: for example, non-strangulating infarction colic (Mair & Pearson, 1995), caecocaecal intussusception (Mair et al., 2000), caecal tympany (Murphy et al., 1997) and non-specific mild medical colic (Uhlinger, 1990). The level of cyathostomin burden associated with each of these conditions is unknown.

HOW CAN WE EFFECTIVELY MANAGE ENCYSTED LARVAL BURDENS TO REDUCE THE RISK OF DISEASE WITHOUT OVERUSING ANTHELMINTICS?

An individual's disease risk can be estimated based on several factors, which are summarised below.

Factor	Considerations
Individual's susceptibility	Age, clinical condition, disease history, level of immunity based on previous exposure
Access to grazing	Amount of grazing time: stabled versus part time grazing versus full time grazing; seasonal variations in grazing pattern
Likely exposure due to management and environmental conditions	Paddock management factors (dung removal, stocking density, paddock resting), seasonal factors (time of year, rainfall and temperature)
Recent test results	Coprological and antibody based test results; including test results of horses that the individual being assessed grazes with

All of these factors are key to understanding cyathostomin exposure and potential disease risk. Based on the risk assessment outcome, appropriate actions can be taken to reduce the risk of infection and, as a consequence, cyathostomin-related disease. Risk can vary over time, depending on age, the presence of concurrent disease, as well as seasonal and management changes, so high-risk horses should be subjected to a follow up risk assessment every 3 months, moderate-risk horses every 6 months and low-risk horses annually, with adjustments to advice given made as necessary. Due to the complexity of assessing overlapping risk factors, an online tool, 'What's Your Worm Risk' (whatsyourwormrisk.com) is available to support veterinary surgeons and their clients in assessing helminth infection risk. This tool evaluates infection risk based on answers to nine questions that have been designed around key principles in equine helminth epidemiology (summarised below).

Risk factor question	Specifics
1. Age and grazing pattern	Horses of different ages have varying susceptibility to cyathostomins; this can affect the horses that they graze with because susceptible horses can pass more worm eggs onto paddocks. Horses under 5 years and over 20 years may be more susceptible to cyathostomins.
2. Stocking density	Knowledge of the number of horses grazing the same area is a key component of a risk analysis to help understand the possible levels of exposure to cyathostomins on a particular paddock. The higher the number of horses grazing a specific area, the higher the level of exposure to worm stages.
3. Grazing with other animal species	Grazing horses with other animal species can reduce the risk of infections because most types of worms do not cross infect between horses and other animals such as cattle or sheep. Liver fluke can infect cattle, sheep and horses and should be considered in the overall risk assessment.
4. Dung removal	Dung removal can reduce infection risk. This practice should be performed regularly (at least twice a week); full, effective removal away from the paddock can considerably reduce the risk of exposure to cyathostomin stages.
5. Introduction of new horses	Introducing new horses to a population increases the risk of new worms or spreading drug-resistant cyathostomins.
6. Worm control quarantine procedures	A lack of quarantine procedures increases infection risk. Ensure appropriate quarantine procedures are followed when new horses enter a herd. Treatment or test and treatment approaches can be undertaken depending on the assessed risk in the incoming horse(s).

Risk factor question	Specifics
7. Faecal egg count (FEC) testing	FEC assessment enables identification of horses that shed higher levels of strongyle eggs that require treatment. Many healthy adult horses will shed no/low levels of strongyle eggs and will not require treatment. The saving of treatments based on the results of FEC tests can help protect the effectiveness of anthelmintics, thus reducing the risk of resistance.
8. Tapeworm saliva or blood testing	Tapeworm testing enables horses with burdens to be identified and treated with appropriate anthelmintics. Using tapeworm testing, many horses will be identified as harbouring no/low burdens so will not be advised for treatment. This saving of treatments can help protect the effectiveness of anti-cestode anthelmintics, thus reducing the risk of resistance.
9. Small redworm blood testing	Small redworm testing can be used in horses at low risk of worm infection (see below). Blood testing low risk horses can help confirm if they have a no/low small redworm burden that does not need specific treatment. This can help reduce worming treatments to protect anthelmintic effectiveness, thus reducing the risk of resistance.

To lower infection risk, it is essential to apply measures that reduce levels of cyathostomin L3 contamination on paddocks. This will impact the burden of encysted larvae that develop in horses that graze those paddocks, while helping to decrease the need for treatments. Key management practices that underpin contamination control and reduce infection risk include:

- Full dung removal at least twice a week (Corbett et al., 2014; Herd, 1986).
- Maintaining a stocking density of at least one acre/horse: higher stocking densities are significantly associated with increased strongyle egg shedding (Joó et al., 2022). The type of horse grazing (for example, healthy adults versus immature horses) will impact the stocking density requirement.
- Resting paddocks for at least 6 months and/or grazing equine paddocks with ruminants in the first half of the grazing season (Eysker et al., 1986). Climatic factors can affect the success of resting approaches; for example, cyathostomin L3 deposited in 1 year reduce greatly by the middle of summer the following year as these stages do not feed and the seasonal increase in temperature leads to more activity depleting their stored food resource.

Adopting these practices can greatly enhance control and reduce the risk of encysted larval burdens accumulating in susceptible horses (especially, those under 5 years or those over 20 years of age).

Many adult horses on well-managed paddocks where contamination control is optimised have low cyathostomin burdens due to the negative binomial distribution of helminths in which approximately 20% of the host population carries/excretes about 80% of the total parasites harboured by the group (Anderson, 1987). Testing populations to identify those horses which do not have high worm burdens or egg excretion can therefore significantly reduce anthelmintic use. The two types of diagnostic tests available to support decisions regarding cyathostomin treatments include:

- FEC tests which estimate strongyle egg shedding levels in faeces
- An ELISA (Small Redworm Blood Test, Austin Davis Biologics) which measures specific antibodies to three cyathostomin recombinant proteins; the presence of these antibodies indicates exposure to infection, with levels measured to these antigens also shown to correlate with cyathostomin burdens up to 10,000 worms (see below).

USING STRONGYLE FEC TO REDUCE PADDOCK CONTAMINATION WITHOUT OVERUSE OF ANTHELMINTICS

In managed populations, it has been demonstrated that 20–30% of horses shed around 80% of the total eggs excreted (Lester et al., 2018; Relf et al., 2013). Egg shedding varies with age, management, time since the last treatment and season. In the UK, FEC are higher in spring/summer and lower in autumn/winter (Duncan, 1974; Wood et al., 2013). Young horses (1–4 years) generally have higher FEC, while seniors (20+ years) also show increased FEC (Adams et al., 2015). Using a treatment threshold of 200–500 eggs per gram (epg) can substantially reduce anthelmintic use (Lester et al., 2018). In practice, FEC tests should be conducted every 8–12 weeks in the grazing season, and, perhaps, more frequently in high-risk groups (Lester & Matthews, 2014). Horses that graze outside all year may benefit from FEC testing in late winter to monitor contamination levels and inform the need for treatment.

FEC tests do not provide information on total worm burdens; they do not account for variable egg shedding in female worms nor do they account for male worms or larval stages. For example, studies that compared strongyle egg counts to cyathostomin counts at necropsy showed no significant associations at higher egg shedding levels (Nielsen et al., 2010). Furthermore, FEC do not bear any relationship to larval numbers which can comprise the majority of a cyathostomin burden (Dowdall et al., 2002). Acquired immunity can limit egg production by cyathostomin female worms (Klei & Chapman, 1999), further highlighting that FEC should not be used to estimate burdens. This is important because horses exhibit considerable ranges in burdens; in one UK study (Ogbourne, 1976), it was demonstrated that in 86 horses presenting at an abattoir, the luminal cyathostomin count ranged from 12,000 to 1,239,000 worms. Likewise, in a US study of 55 horses (Reinemeyer et al., 1986), the reported range of adult burdens was 680 to 663,100 cyathostomins.

As FEC were recognised as unreliable in assessing the total cyathostomin burden of horses, especially in individuals with high

TABLE 1 Serum score cut-off thresholds used in the cyathostomin ELISA (Small Redworm Blood Test).

	Serum score threshold for >1000 cyathostomins: 14.37	Serum score threshold for >5000 cyathostomins: 15.61	Serum score threshold for >10,000 cyathostomins: 30.46
Sensitivity (95% CI)	97.65% (91.76–99.71%)	96.10% (89.03–99.19%)	91.55% (82.51–96.84%)
Specificity (95% CI)	85.19% (66.27–95.81%)	71.43% (53.70–85.36%)	75.61% (59.70–87.64%)

Note: Sensitivity and specificity values for each threshold are shown along with 95% confidence intervals (CI) in parenthesis for each parameter. Adapted from Lightbody et al. (2024).

proportions of encysted larval stages, and because of the pathogenic potential of these encysted larvae, previous practices were to treat all horses with a larvicidal anthelmintic in autumn/winter or at the end of the grazing season. Due to extensive benzimidazole resistance, moxidectin is often used for this purpose (Tzelos et al., 2019). Such treatments are likely to contribute to moxidectin resistance.

THE CYATHOSTOMIN ELISA

This test measures serum IgG(T) levels specific to three recombinant antigens from *C. catinatum*, *C. nassatus* and *C. longibursatus*, the most common species globally (Bellaw & Nielsen, 2020). The test was developed from early studies that showed increased serum IgG(T) responses to cyathostomin larval antigens within 5 weeks of a primary experimental infection (Dowdall et al., 2002). These responses were principally directed at ~20 and ~25 kDa larval antigen complexes as detected by SDS-PAGE analysis. Subsequently, levels of IgG(T) to the purified antigen complexes were shown to correlate with cyathostomin larval burdens in infected horses (Dowdall et al., 2003). Collecting and harvesting the larval antigens in these antigen complexes presents technical and ethical challenges, so genes encoding immunodominant components of the antigen complexes were identified, and 14 representative recombinant proteins expressed and evaluated for their diagnostic potential (McWilliam et al., 2010; Mitchell et al., 2016; Tzelos et al., 2020). In these studies, two cyathostomin-specific proteins, Gut Associated Larval Antigen (GALA) and Cyathostomin Diagnostic Antigen (CID), were identified, cloned and expressed from several common species. Further analysis demonstrated that a combination of three recombinant proteins from *C. nassatus* (a CID protein), *C. catinatum* (a GALA protein) and *C. longibursatus* (a GALA protein) showed potential in providing diagnostic information relating to cyathostomin infection as the levels of antigen-specific antibody measured correlated with total burdens up to a threshold of 5000 worms (Tzelos et al., 2020). The GALA protein was found to be detected in EL3 and later encysted larval stages (McWilliam et al., 2010), while the CID transcript was identified in LL3/DL4 and lumenal stages (Tzelos et al., 2020). For these reasons, the cyathostomin ELISA provides diagnostic information relating to all host stages of these nematodes.

A commercial ELISA based on these three recombinant proteins was subsequently optimised and validated using gold standard samples from horses for which cyathostomin larval and adult worm counts were available (Lightbody et al., 2024). The optimised ELISA demonstrated high Receiver Operating Characteristic Area Under the Curve (ROC-AUC) values for cyathostomin count thresholds up to, and including, 10,000 mucosal and luminal cyathostomins (ROC-AUC range 0.910–0.956; Lightbody et al., 2024). At higher cyathostomin thresholds, ROC-AUC values were less than 0.9, the level accepted as being of excellent diagnostic utility by Swets (1988). This test incorporates equine IgG calibrators for quantification and quality control on each ELISA plate, and a 'serum score' is calculated based on antigen-specific IgG(T) measured in each sample. The derived serum score can then be assessed against three thresholds which correspond to burdens of 1000, 5000 and 10,000 cyathostomins (Table 1). These three thresholds were selected based on a statistical analysis in the validation study of Lightbody et al. (2024) where a range of serum scores were assessed from ROC curve coordinates by examining the trade-off of diagnostic sensitivity against specificity. Serum scores in the maximal zone of the Youden index (i.e. J = sensitivity + specificity − 1) were interrogated to select appropriate cut-off values for the assay: these being 1000 (serum score cut-off: 14.37), 5000 (serum score cut off: 15.61) and 10,000 cyathostomins (serum score cut-off: 30.46). Following this validation step of the optimised ELISA, Lightbody et al. (2024) studied the test's performance in groups of horses kept under different management and climatic conditions. Using strongyle FEC data from these groups, they analysed the relationship between FEC and antigen-specific serum scores. Their findings showed that even using the lowest 1000 cyathostomin burden cut-off (serum score: 14.37), compared to a blanket treatment approach, the ELISA could reduce anthelmintic treatments by 41%, regardless of the helminth risk level identified for each group. Analysis of recent FEC results from these groups showed that there was a significant relationship of FEC to the derived serum scores, with 70% of FEC-negative horses found to be below the 1000 cyathostomin serum score threshold. The analysis indicated that the cyathostomin ELISA would be most effective in reducing anthelmintic use in horses at low risk of infection, and based on these findings, guidelines for use of the test were developed (Table 2).

In practice, the cyathostomin ELISA can be used as a tool when FEC testing does not provide diagnostically useful data; for example, when assessing the need for treatment in autumn and winter in northern temperate areas. Applying the test in low-risk horses can result in considerable reductions in treatments compared to a blanket approach. For example, data from a low-risk sport horse cohort (n = 981 horses) demonstrated that 62% of these horses returned serum scores

TABLE 2 Factors to consider when using the cyathostomin ELISA for informing anthelmintic treatment decisions.

	Factors contributing to low infection risk	Factors contributing to high infection risk
Management factors[a]	Closed herd, dung removed >2 times per week, low stocking density (<2 horses/acre), no young stock (<5 years) or limited access to pasture (e.g. sport or racehorse)[b]	Open herd, dung not removed/removed sporadically, high stocking density (>2 horses/acre), a high proportion of young stock (<5 years) present, anthelmintic resistance reported[b]
Recent faecal egg count results to consider	Concurrent and recent individual or all group FEC results <200 EPG	Individual or high proportion of group FEC results 200 EPG+
Apply test?	Yes	No

[a]Individual factors can determine the decision to apply the test, rather than the combination of all factors listed.

[b]'Closed' refers to a group where new members are never or infrequently introduced. 'Open' refers to a group where new members are frequently introduced or leave.

below the lowest serum score threshold for 1000 cyathostomins and, of the horses tested, only 19% had serum score results which were above the 10,000 burden threshold (Matthews et al., 2024). The test also has value when certain risk factors are unknown. For example, in a study of 56 UK racehorses (Matthews, 2024), presumed to be at low risk of infection, serum scores in samples taken in December demonstrated that only 32% of horses were below the 1000 cyathostomin threshold, with 48% below the 10,000 cyathostomin threshold. Further investigation identified that each horse had 30 min turnout to a small paddock every day and that dung was not removed from this paddock, providing a source of L3 infection. On this basis, the ELISA results highlighted the requirement to improve management by removing dung daily from the paddock. The racehorses previously had received regular all-group anthelmintic treatments, so although ELISA testing recommended that a proportion of the group be wormed, using the test led to a reduction in treatment frequency as well as provided insights for the veterinary surgeon to advise improvements in parasite management.

As the cyathostomin ELISA demonstrates a high sensitivity for detecting negligible/low burdens in horses, it can also be used to rule out cyathostomins in the aetiology of disease in horses, for example in cases that present with non-specific colic. Although not recommended as a standalone diagnostic test in cases of acute larval cyathostominosis, the ELISA has been reported to provide useful information in disease outbreaks (Walshe et al., 2021). In this study, all horses with larval cyathostominosis that were tested returned serum scores in excess of 50.0, a level reported as 'off-scale' as antibody levels measured were outside the linear gradient of the IgG calibration curve used to generate each serum score.

INTERPRETING THE RESULTS OF THE CYATHOSTOMIN ELISA

Cyathostomin ELISA results should be interpreted individually for each tested horse with reference to a risk assessment (Figure 1) and the decision to administer anthelmintic at a specific serum score threshold based on the impact of treating at the threshold selected (Matthews et al., 2023). If the lower serum score threshold is selected, more treatments will be administered; this needs to be considered in respect of anthelmintic resistance selection, whilst at the higher serum score threshold, fewer horses will be treated. In this case, one needs to consider the transmission risk relating to those horses that would remain untreated with anthelmintic. The decision regarding which serum score threshold to select for each horse should be based on individual/group characteristics (age, clinical condition), as well as local management practices (stocking density, pasture hygiene practices etc). In higher helminth transmission situations (for example, where there are several horses, including youngsters, grazing paddocks at stocking densities of less than 1 acre/horse, and/or where there is intermittent or no dung removal), a lower serum score threshold selected for anthelmintic treatment may be more appropriate. In lower-risk environments (e.g. horses grazing at a low stocking density where dung is removed daily, or where horses are not at grass for significant periods), a higher serum score threshold may be more applicable.

OTHER CONSIDERATIONS FOR USING THE CYATHOSTOMIN ELISA

Residual antibodies from past infections can impact test results after treatment. Equine IgG(T) serum half-life ranges between 21 and 35 days (Sheoran et al., 2000; Wilson et al., 2001) so to avoid false positive results, it is recommended to wait 4 months after treatment before blood testing. Foals develop IgG(T) responses to strongyle infections within 6–12 weeks of birth. To allow time for colostral-derived antigen specific antibodies to decrease sufficiently (Lightbody et al., 2024), foals can be tested from 3 months old; however, consideration of ascarid infections should be prioritised in young foals and strategic treatments applied if necessary.

CONCLUSIONS

Improving pasture management and testing to inform anthelmintic use are key to decelerating anthelmintic resistance in horses, but moving the sector away from calendar-based treatment programmes remains challenging. Recent studies show that many owners still

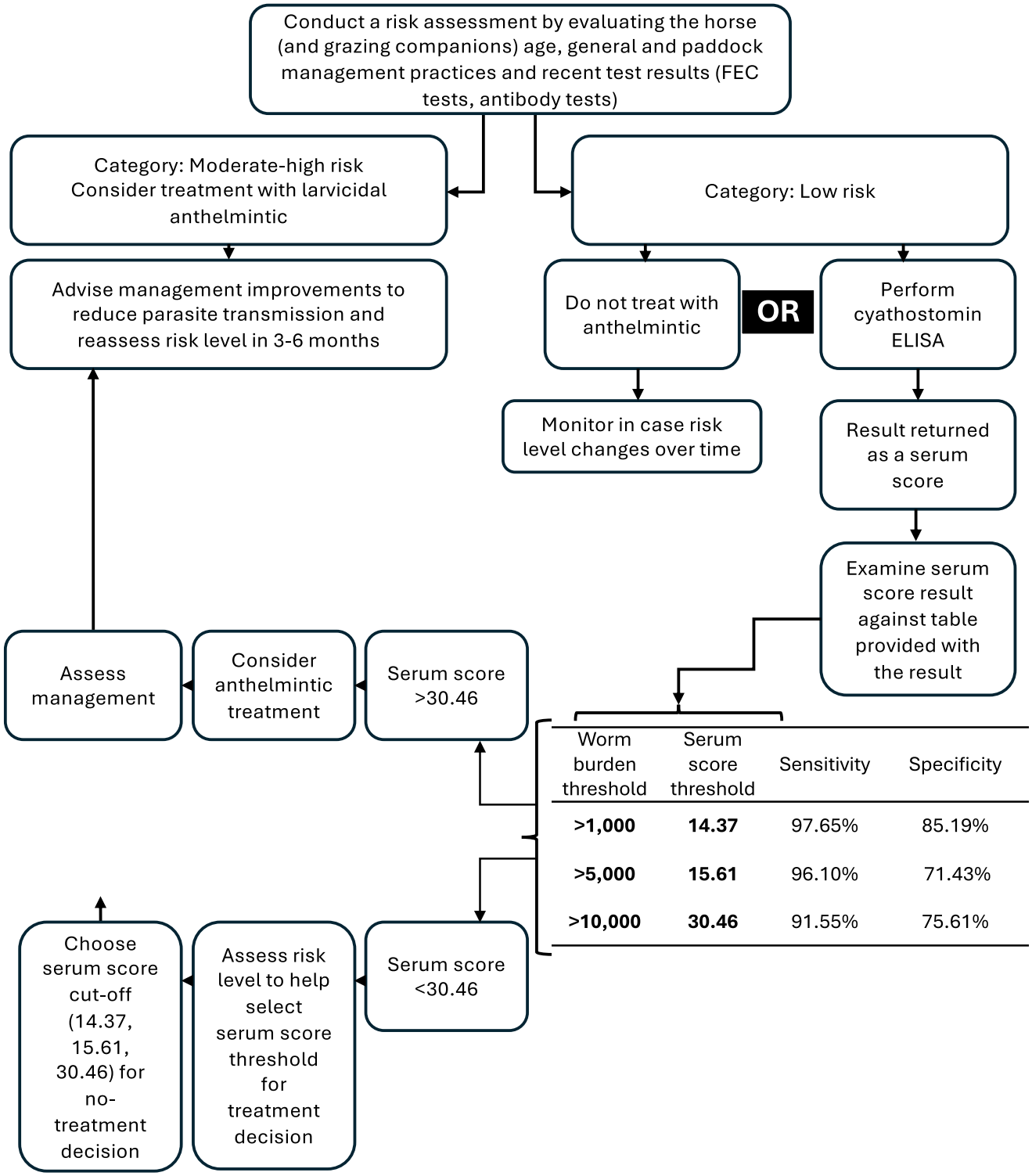

FIGURE 1 A decision tree providing information for options for cyathostomin larvicidal treatments of horses in autumn/winter in northern temperate regions.

prefer to administer regular all-group anthelmintic treatments that are thought to provide a perceived protection against disease (Elghryani et al., 2019; Walshe et al., 2023) and despite good self-reported uptake of FEC testing and improved pasture management, prophylactic worming treatments are still commonplace (Mair et al., 2023; Shrubb et al., 2025a, 2025b). It has been proposed that the fear of disease due to a lack of worming leads to these unnecessary treatments, regardless of the risk that anthelmintic resistance poses (Rose Vineer et al., 2017). One practice proving particularly intractable to address is the prophylactic therapy for encysted cyathostomins in autumn and winter (McTigue et al., 2022). Tools such as the cyathostomin ELISA can help mitigate uncertainty around withholding treatment by allowing

informed decisions to be made about anthelmintic applications and so reduce prophylactic treatment behaviours. This test is designed to help veterinary surgeons and their clients adopt more evidence-based approaches when considering these treatments. In a similar vein, it has been found that when addressing antibiotic overuse, data generation and access, along with associated veterinary advice, have been found to help improve end-user compliance in preserving these medicines (Guenin et al., 2023). It is hoped that, similarly, the use of FEC and antibody-based tests that generate data will help veterinary surgeons develop an evidence basis from which they can build advice and also use as monitoring tools to help horse owners engage in more sustainable approaches to parasite control.

AUTHOR CONTRIBUTIONS

J. B. Matthews: Conceptualization; writing – original draft. **T. S. Mair:** Conceptualization; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

Jacqueline B Matthews is an employee of Austin Davis Biologics, the company that provides the cyathostomin ELISA (Small Redworm Blood Test) as a diagnostic service, and is the lead inventor of the test, and so has a financial interest in some of the content of this review.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed for this review.

ETHICS STATEMENT

Not applicable.

INFORMED CONSENT

Not applicable.

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REFERENCES

Adams, A.A., Betancourt, A., Barker, V.D., Siard, M.H., Elzinga, S., Bellaw, J.L. et al. (2015) Comparison of the immunologic response to anthelmintic treatment in old versus middle-aged horses. *Journal of Equine Veterinary Science*, 35, 873–881.

Anderson, R.M. (1987) The role of mathematical models in helminth population biology. *International Journal for Parasitology*, 17, 519–529.

Bellaw, J.L. & Nielsen, M.K. (2020) Meta-analysis of cyathostomin species-specific prevalence and relative abundance in domestic horses from 1975-2020: emphasis on geographical region and specimen collection method. *Parasites and Vectors*, 13, 509.

Chapman, M.R., French, D.D., Taylor, H.W. & Klei, T.R. (2002) One season of pasture exposure fails to induce a protective resistance to cyathostomes but increases the number of hypobiotic third-stage larvae. *Journal of Parasitology*, 88, 678–683.

Corbett, C.J., Love, S., Moore, A., Burden, F.A., Matthews, J.B. & Denwood, M.J. (2014) The effectiveness of faecal removal methods of pasture management to control the cyathostomin burden of donkeys. *Parasites and Vectors*, 7, 48.

Dowdall, S.M., Matthews, J.B., Mair, T., Murphy, D., Love, S. & Proudman, C.J. (2002) Antigen-specific IgG(T) responses in natural and experimental Cyathostominae infection in horses. *Veterinary Parasitology*, 106, 225–242.

Dowdall, S.M.J., Proudman, C.J., Love, S., Murphy, D., Klei, T.R. & Matthews, J.B. (2003) Purification and analyses of the specificity of two putative diagnostic antigens for larval cyathostomin infection in horses. *Research in Veterinary Science*, 75, 223–229.

Duncan, J. (1974) Field studies on the epidemiology of mixed strongyle infection in the horse. *The Veterinary Record*, 94, 337–345.

Elghryani, N., Duggan, V., Relf, V. & de Waal, T. (2019) Questionnaire survey on helminth control practices in horse farms in Ireland. *Parasitology*, 146, 873–882.

Eysker, M., Jansen, J. & Mirck, M.H. (1986) Control of strongylosis in horses by alternate grazing of horses and sheep and some other aspects of the epidemiology of Strongylidae infections. *Veterinary Parasitology*, 19, 103–115.

Giles, C.J., Urquhart, K.A. & Longstaffe, J.A. (1985) Larval cyathostomiasis (immature trichonema-induced enteropathy): a report of 15 clinical cases. *Equine Veterinary Journal*, 17, 196–201.

Guenin, M.J., Studnitz, M. & Molia, S. (2023) Interventions to change antimicrobial use in livestock: a scoping review and an impact pathway analysis of what works, how, for whom and why. *Preventive Veterinary Medicine*, 220, 106025.

Herd, R.P. (1986) Epidemiology and control of equine strongylosis at Newmarket. *Equine Veterinary Journal*, 18, 447–452.

Joó, K., Trúzsi, R.L., Kálmán, C.Z., Ács, V., Jakab, S., Bába, A. et al. (2022) Evaluation of risk factors affecting strongylid egg shedding on Hungarian horse farms. *Veterinary Parasitology: Regional Studies and Reports*, 27, 100663.

Klei, T.R. & Chapman, M.R. (1999) Immunity to cyathostome infections. *Veterinary Parasitology*, 85, 123–136.

Lester, H.E. & Matthews, J.B. (2014) Faecal worm egg count analysis for targeting anthelmintic treatment in horses: points to consider. *Equine Veterinary Journal*, 46, 139–145.

Lester, H.E., Morgan, E.R., Hodgkinson, J.E. & Matthews, J.B. (2018) Analysis of strongyle egg shedding consistency in horses and factors that affect it. *Journal of Equine Veterinary Science*, 60, 113–119.

Lichtenfels, J.R., Kharchenko, V.A., Krecek, R.C. & Gibbons, L.M. (1998) An annotated checklist by genus and species of 93 species level names for 51 recognized species of small strongyles (Nematoda: Strongyloidea: Cyathostominea) of horses, asses and zebras of the world. *Veterinary Parasitology*, 79, 65–79.

Lightbody, K.L., Austin, A., Lambert, P.A., von Samson-Himmelstjerna, G., Jürgenschellert, L., Krücken, J. et al. (2024) Validation of a serum ELISA test for cyathostomin infection in equines. *International Journal for Parasitology*, 54, 23–32.

Love, S. (1992) Role of equine strongyles in the pathogenesis of colic and current options for prophylaxis. *Equine Veterinary Journal. Supplement*, 13, 5–9.

Love, S. & Duncan, J.L. (1992) The development of naturally acquired cyathostome infection in ponies. *Veterinary Parasitology*, 44, 127–142.

Mair, T.S. & Pearson, G.R. (1995) Multifocal non-strangulating intestinal infarction associated with larval cyathostomiasis in a pony. *Equine Veterinary Journal*, 27, 154–155.

Mair, T.S., Schofield, I., Shrubb, J.L. & Rendle, D.I. (2023) Understanding UK parasite control practices: a horse owner survey. *Equine Veterinary Journal*, 55(S58), 13.

Mair, T.S., Sutton, D. & Love, S. (2000) Caeco-caecal intussusception in cyathostomosis. *Equine Veterinary Journal. Supplement*, 32, 77–80.

Mathieson, A.O. (1964) *A study into the distribution of, and tissue responses associated with, some internal parasites of the horse*. Thesis, University of Edinburgh.

Matthews, J.B. (2014) Anthelmintic resistance in equine nematodes. *International Journal for Parasitology: Drugs and Drug Resistance*, 4, 310–315.

Matthews, J.B. (2024) To worm or not to worm: should we worm horses in training? *European Trainer*, 87, 42–44.

Matthews, J.B., Peczak, N. & Engeham, S. (2024) An update on the latest developments in testing for equine helminths. *In Practice*, 46, 34–41.

Matthews, J.B., Peczak, N. & Lightbody, K.L. (2023) The use of innovative diagnostics to inform sustainable control of equine helminth infections. *Pathogens*, 12, 1233.

McTigue, F.E., Mansbridge, S.C. & Pyatt, A.Z. (2022) Equine anthelmintic resistance: horse owner and yard manager perception of the barriers affecting strategic control measures in England. *Veterinary Science*, 9, 560.

McWilliam, H.E.G., Nisbet, A.J., Dowdall, S.M.J., Hodgkinson, J.E. & Matthews, J.B. (2010) Identification and characterisation of a potential immunodiagnostic marker for larval cyathostominosis. *International Journal for Parasitology*, 40, 265–275.

Mfitilodze, M.W. & Hutchinson, G.W. (1987) Development and survival of free-living parasites of equine parasites under laboratory conditions. *Veterinary Parasitology*, 23, 121–123.

Mitchell, M.C., Tzelos, T., Handel, I., McWilliam, H.E.G., Hodgkinson, J.E., Nisbet, A.J. et al. (2016) Development of a recombinant protein-based ELISA for diagnosis of larval cyathostomin infection. *Parasitology*, 143, 1055–1066.

Murphy, D., Keane, M.P., Chandler, K.J. & Goulding, R. (1997) Cyathostome-associated disease in the horse: investigation and management of four cases. *Equine Veterinary Education*, 9, 247–252.

Murphy, D. & Love, S. (1997) The pathogenic effects of experimental cyathostome infections in ponies. *Veterinary Parasitology*, 70, 99–110.

Nielsen, M.K. (2022) Anthelmintic resistance in equine nematodes: current status and emerging trends. *International Journal for Parasitology: Drugs and Drug Resistance*, 20, 76–88.

Nielsen, M.K., Baptiste, K.E., Tolliver, S.C., Collins, S.S. & Lyons, E.T. (2010) Analysis of multiyear studies in horses in Kentucky to ascertain whether counts of eggs and larvae per gram of feces are reliable indicators of numbers of strongyles and ascarids present. *Veterinary Parasitology*, 174, 77–84.

Ogbourne, C.P. (1975) Epidemiological studies on horses infected with nematodes of the family Trichonematidae (Witenberg, 1925). *International Journal for Parasitology*, 5, 667–672.

Ogbourne, C.P. (1976) The prevalence, relative abundance and site distribution of nematodes of the subfamily Cyathostominae in horses killed in Britain. *Journal of Helminthology*, 50, 203–213.

Poynter, D. (1967) Some tissue reactions to the nematode parasites of animals. *Advances in Parasitology*, 4, 321–383.

Ramsey, Y.H., Chistley, R.M., Matthews, J.B., Hodgkinson, J.E., McGoldrick, J. & Love, S. (2004) Seasonal development of Cyathostominae larvae on pasture in a northern temperate region of the United Kingdom. *Veterinary Parasitology*, 119, 307–318.

Reid, S.W., Mair, T.S., Hillyer, M.H. & Love, S. (1995) Epidemiological risk factors associated with a diagnosis of clinical cyathostomiasis in the horse. *Equine Veterinary Journal*, 27, 127–130.

Reinemeyer, C.R., Smith, S.A., Gabel, A.A. & Herd, R.P. (1986) Observations on the population dynamics of five cyathostome nematode species of horses in the northern USA. *Equine Veterinary Journal*, 18, 121–124.

Relf, V.E., Morgan, E.R., Hodgkinson, J.E. & Matthews, J.B. (2013) Helminth egg excretion with regard to age, gender and management practices on UK thoroughbred studs. *Parasitology*, 140, 641–652.

Rendle, D., Austin, C.J., Bowen, M., Cameron, I., Furtado, T., Hodgkinson, J.E. et al. (2019) Equine de-worming: a consensus on current best practice. *UK-Vet Equine*, 3, 1–15.

Rose Vineer, H., Vande Velde, F., Bull, K., Claerebout, E. & Morgan, E.R. (2017) Attitudes towards worm egg counts and targeted selective treatment against equine cyathostomins. *Preventive Veterinary Medicine*, 144, 66–74.

Sheoran, A.S., Timoney, J.F., Holmes, M.A., Karzenski, S.S. & Crisman, M.V. (2000) Immunoglobulin isotypes in sera and nasal mucosal secretions and their neonatal transfer and distribution in horses. *American Journal of Veterinary Research*, 61, 1099–1105.

Shrubb, J., Robinson, N., Rendle, D., Schofield, I., Scott, S., Crabtree, J. et al. (2025a) Project WORMS (working to overcome resistance and make for a sustainable future): horse owner survey of equine parasite control. Part 1. Management factors. *Equine Veterinary Education*. Available from: https://doi.org/10.1111/eve.14112

Shrubb, J., Robinson, N., Rendle, D., Schofield, I., Scott, S., Crabtree, J. et al. (2025b) Project WORMS (working to overcome resistance and make for a sustainable future): horse owner survey of equine parasite control. Part 2. Anthelmintic use. *Equine Veterinary Education*. Available from: https://doi.org/10.1111/eve.14116

Smith, H.J. (1976) Strongyle infections in ponies: II. Reinfection of treated animals. *Canadian Journal of Comparative Medicine*, 40, 334–340.

Swets, J.A. (1988) Measuring the accuracy of diagnostic systems. *Science*, 240, 1285–1293.

Tiunov, V.I. (1953) Development of the nematode *Trichonema longibursatum* in the body of the horse. *Trudy Vsesoyuznogo Instituta Gel'mintologii*, 5, 65–67.

Tzelos, T., Easton, S., Morgan, E.R., Hodgkinson, J.E. & Matthews, J.B. (2019) Uptake of targeted anthelmintic treatments in the UK horse-owning population assessed by questionnaire. *Veterinary Parasitology*, 274, 108926.

Tzelos, T., Geyer, K., Mitchell, M., McWilliam, H.E.G., Kharchenko, V.O., Burgess, S.T.G. et al. (2020) Characterisation of serum IgG(T) responses to potential diagnostic antigens for equine cyathostomins. *International Journal for Parasitology*, 50, 289–298.

Uhlinger, C.A. (1990) Effects of three anthelmintic schedules on the incidence of colic in horses. *Equine Veterinary Journal*, 22, 251–254.

Walshe, N., Mulcahy, G., Crispie, F., Cabrera-Rubio, R., Cotter, P., Jahns, H. et al. (2021) Outbreak of acute larval cyathostominosis – a "perfect storm" of inflammation and dysbiosis. *Equine Veterinary Journal*, 53, 727–739.

Walshe, W., Burrell, A., Kenny, U., Mulcahy, G., Duggan, V. & Regan, A. (2023) A qualitative study of perceived barriers and facilitators to sustainable parasite control on thoroughbred studs in Ireland. *Veterinary Parasitology*, 317, 109904.

Wilson, W.D., Mihaly, J.E., Hussey, S. & Lunn, D.P. (2001) Passive transfer of maternal immunoglobulin isotype antibodies against tetanus and influenza and their effect on the response of foals to vaccination. *Equine Veterinary Journal*, 33, 644–650.

Wood, E.L.D., Matthews, J.B., Stephenson, S., Slote, M. & Nussey, D.H. (2013) Variation in faecal egg counts in horses managed for conservation purposes: individual egg shedding consistency, age effects and seasonal variation. *Parasitology*, 140, 115–128.

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