Guidelines for the control of worms in equines

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in collaboration with

The Horse Trust

Contents

1. Summary

Most grazing horses and other equids are infected with parasitic worms. The majority of animals show no outward signs of infection but in some individuals, especially younger horses and ponies, worms can persist in high numbers to cause clinical signs ranging from mild colic and weight loss to life-threatening colic or diarrhoea. Younger animals are more vulnerable to infection because it can take some time for an effective immune response to develop. The key to effective control is to manage these parasites in such a way that high worm burdens do not build up within individuals. Control strategies must aim to reduce levels of worm infection in the environment by using good pasture management. This should be used in combination with specific targeting of dewormers (anthelmintics) against certain types of worms or stages of worms, ideally by using diagnostic tests. Because dewormer resistance is an increasing issue, it is important that control strategies ensure that dewormers are used in a way that non-essential treatments are avoided.

This guide has been written to provide up-to-date information on;

1. common types of worms that affect horses
2. dewormers used to treat and control these worms
3. dewormer resistance
4. sustainable worm control strategies.

This information provides essential building blocks on which 'best practice' worm control can be implemented.

2. Worms

Horses can be infected with a range of parasitic worms ('helminths'); these include roundworms ('nematodes'), tapeworms ('cestodes') and flatworms ('trematodes'). These worms are found world-wide. Table 1 summarises important worm species that can affect horses.

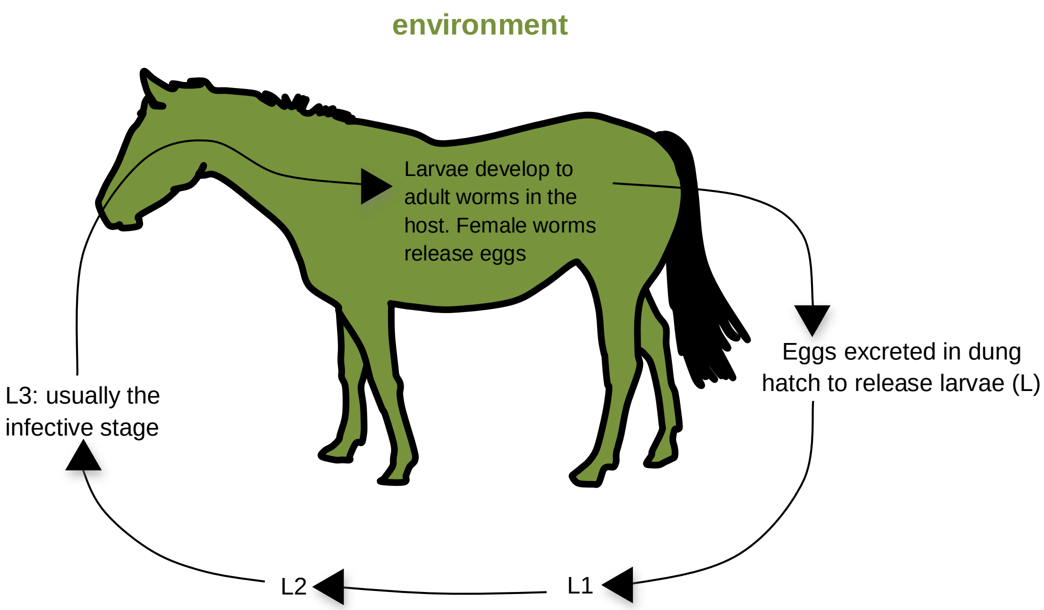
Table 1. Common worms that can infect equines, their site of infection, the type of stock most likely to be infected, common clinical manifestations and the time measured between initial infection until eggs are detectable in dung.

Worm species (common name)	Where adult worms found	Type of stock *most likely* to be affected	Possible clinical signs	Time from first infection to eggs in dung
Roundworms				
Strongyloides westeri (threadworm)	Small intestine	Young foals (i< 6 months)	Clinical signs rare. Diarrhoea, limb dermatitis	1-2 weeks
Parascaris spp. (roundworm, ascarid)	Small intestine	Youngsters, to 2 years-old	Weight loss, potbelly, poor hair coat, slow growth, colic, nasal discharge, cough.	10-12 weeks
Cyathostomins (small redworm, small strongyle)	Large intestine	All ages, but high burdens more likely in 1-3 year-olds	Weight loss, diarrhoea, colic. Signs associated with mass emergence of immature worms from gut wall.	2-3 months (but may be extended to 2 years)
Strongylus vulgaris (large redworm)	Large intestine (larvae in blood vessels)	All ages, but high burdens more likely in 1-3 year-olds	Colic, anaemia, ill thrift.	6-7 months
Oxyuris equi (pinworm)	Large intestine, rectum	6 months and over	Itching around the tail head.	5 months
Dictyocaulus arnfieldi (lungworm)	Lungs	6 months and over	Occasional cause of respiratory disease in horses that graze with donkeys. Chronic cough, poor condition.	5-6 weeks. Worms do not mature in adult horses/ponies. Cycle develops in foals and donkeys, who are main sources of infection.
Tapeworms				
Anoplocephala perfoliata (tapeworm)	Large/small intestine junction	6 months and over	Unthriftiness, colic	6-10 weeks
Flatworms				
Fasciola hepatica (liver fluke)	Liver and bile ducts	6 months and over	Weight loss, anaemia, swelling under chin, chest	10-12 weeks

			or abdomen, colic, diarrhoea.	

Non-worm parasites such as bots are also sometimes present; these do not usually cause clinical problems in horses and ponies.

The way in which worms are spread and how they develop and persist in the host is key to understanding how to prevent transmission, control infection and avoid disease. The study of how worms are spread is called 'epidemiology'. Epidemiology is driven by **worm life cycles**. Below is a cartoon of a typical worm life cycle.



Generally, adult worms live in the gut (small or large intestine). Horses and ponies can be infected with worms that live in other organs such as the lungs and liver, but these are less commonly found than gut worms. In most cases, adult worms release **eggs** that pass into the environment in dung. In the egg are **larvae** which undergo several developmental larval (L) stages (L1-L5). In most cases, L1 hatch from eggs and develop to L3 in dung. L3 are motile and move from dung onto blades of grass on a film of water.

Usually, **L3 are infective** and are transmitted by **ingestion**. The warmer the temperature, the faster larval stages develop to L3. In warm weather (i.e. 30^{o}C plus), eggs hatch and develop to L3 in as short as 2-3 days, although only a small proportion of larvae survive if such temperatures persist. At cooler temperatures, development to L3 takes several weeks and stops below <8^{o}C. L3 are surrounded by the 'skin' (sheath) of the L2, and this protects L3 from drying out. The sheath prevents L3 from feeding so they survive on a limited amount of energy stored in their intestines. Once this energy is used up, L3 die. How quickly this happens is proportional to the environmental temperature. In warm weather, energy stores are used up quicker as L3 move around faster. These aspects of larval development and survival affect how long worm-contaminated pasture should not be used for grazing before it is considered as 'safe' (see below).

For some worms, **larvae** are not released from eggs but **develop in the egg**. In these cases, eggs are resistant and can be difficult to clear from the environment. This needs to be considered in the design of control programmes.

Once the infective stage is ingested, larvae can develop wholly to adult worms in the gastrointestinal system or undergo a migratory phase through tissues. These variables are summarised below for common worm types. This knowledge helps in understanding the design of sustainable control programmes.

a. Roundworms (nematodes)

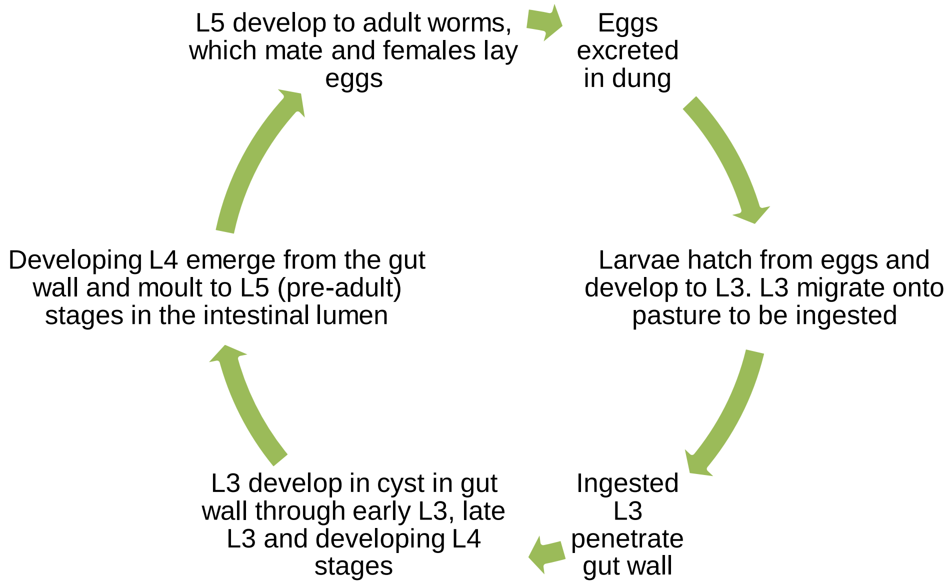
Strongyles

Strongyles are extremely common. The adult worms are found in the large intestine (caecum, colon) and are 1-5 cm long. There are two types of strongyle:

- small strongyles (cyathostomins)
- large strongyles

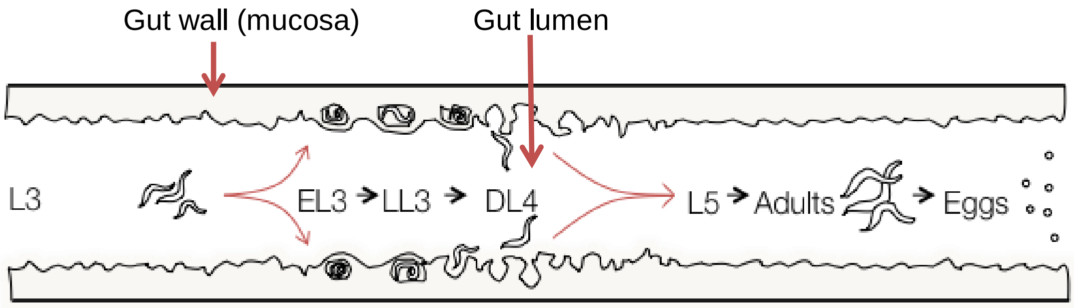
Small strongyles

These are the commonest worms worldwide and almost all grazing horses are infected with small strongyles. Adult worms are hair-like (~1 cm long). There are around 50 small strongyle species; however, the life cycle and epidemiology of the species is similar and they can be treated as a single group. Shortly after ingestion, small strongyle larvae enter the wall of the large intestine (see life cycle below), where a capsule develops around each worm; hence the term **encysted larvae**.



The length of time larvae develop within cysts is variable (a few weeks-many months). Encysted larvae can build up in very high numbers; up to several million in some horses. Encysted larvae have various stages: early third stage larva (EL3) that mature progressively to late third stage larvae (LL3), then developing fourth-stage larvae (DL4).

The cartoon below depicts the stages of small strongyles within the gut (image, Dr Hamish McWilliam, Melbourne University).



The factors that determine how long larvae take to mature are not known, but could be associated with age, immunity, season or total number of worms present. Within a few weeks of emergence, larvae mature to adults, which mate, and the females lay **eggs, which are excreted in dung**.

Encysted larvae are important because when they emerge in large numbers, they cause a severe colitis known as **larval cyathostominosis**. Usually, larval cyathostominosis occurs seasonally (late autumn-spring), and causes inflammation of the gut lining, impaired gut motility and sudden onset diarrhoea, weight loss and colic. Larval cyathostominosis has a poor prognosis and is considered one of the most serious parasite-related diseases.

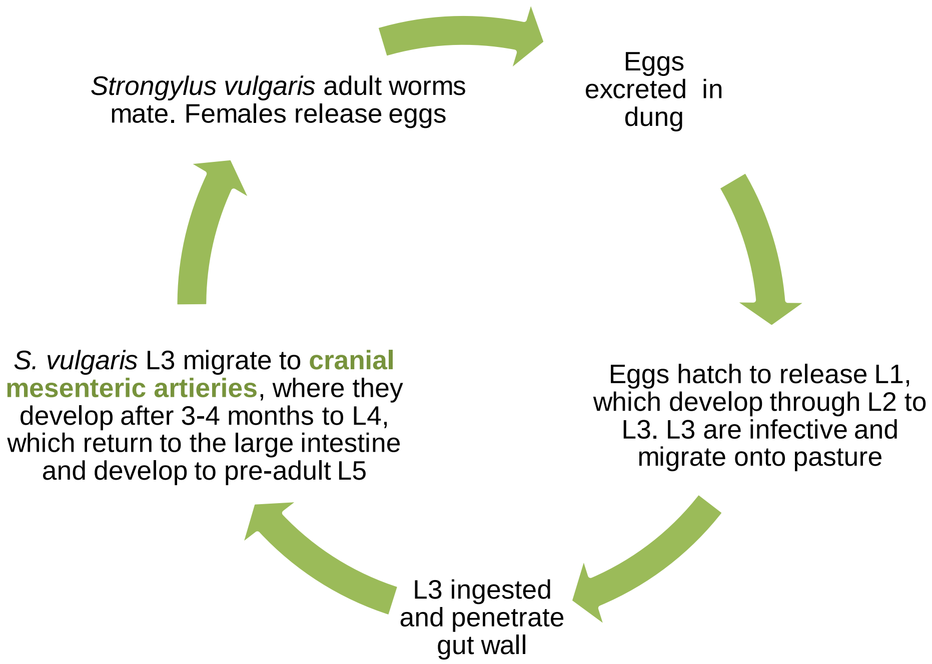
Large intestine of a larval cyathostominosis case at post mortem demonstrating large numbers of encysted larvae (black dots) in the gut lining.

Horses of all ages can be infected with small strongyles, although **younger horses** (1-5 year-olds) tend to be more predisposed to high levels of small strongyle infection and clinical disease.

Foals acquire infection when they start grazing. Although immunity starts to develop after exposure to worms, it varies among individuals. Most mature horses develop good immunity and have low levels of small strongyle infection. These individuals excrete low levels of worms eggs in dung (‘low shedders’). A small proportion (usually <20%) of adult horses have higher burdens. These individuals have greater dung egg excretion ('high shedders'). In practice, this type of worm distribution in a herd means that a **large proportion of individuals have low burdens and as a consequence, low worm egg shedding levels**, even in the absence of dewormer treatments. Different levels of egg shedding can be identified by undertaking **faecal egg count tests**. How these can be used in worm control strategies is explained in Section 5, 'Sustainable Control'.

Large strongyles

Large strongyle adults reach up to 5 cm in length. Horses are infected with these worms following ingestion of L3 from pasture (see life cycle, below). After ingestion, large strongyle L3 penetrate the intestinal wall and migrate through various tissues for 6-11 months. The migratory route depends on the worm species. The focus here is ***Strongylus vulgaris*** as this species can cause severe disease.

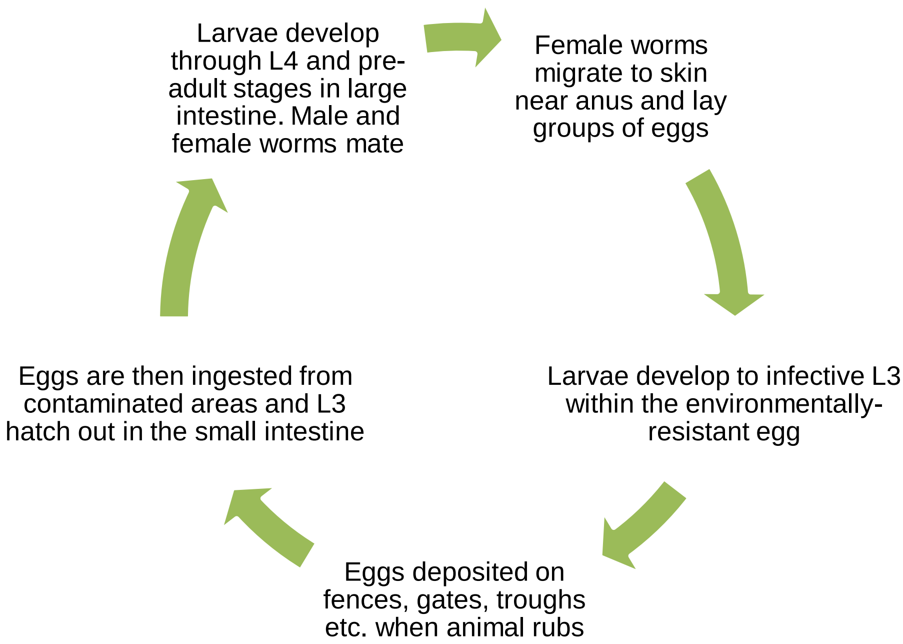


The cranial mesenteric arteries supply blood to the intestine. Here, *S. vulgaris* larvae cause damage resulting in weakening of artery walls, leading to malformed arteries. This causes abnormal blood flow and the formation of blood clots. The clots attach to the artery walls but can break free, travel downstream to block smaller vessels, the result of which is to restrict blood flow to the intestine. This lack of blood supply to the intestine causes a **life-threatening colic** if not treated promptly by surgery.

S. vulgaris is now quite uncommon in developed regions due to high usage of broad spectrum macrocyclic lactone dewormers (see below).

Oxyuris equi

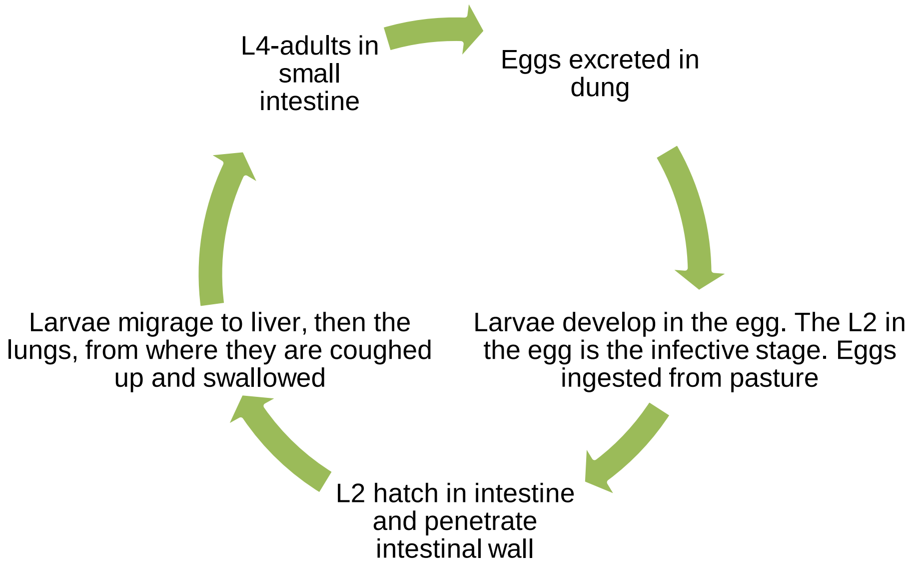
This is the equine pinworm. The adult worms are white/grey and live in the colon the rectum. The worms have a long tale that tapers to a point. The females can reach up to 10 cm in length. Horses of all ages can be infected with pinworm. Many horses are infected without showing clinical signs, but a small proportion can have repeated infections which can lead to signs, which vary from **mild to intense itching of the tail head**. The life cycle is shown below.



Female worms lay eggs in yellow-grey masses on **skin**. After laying eggs, females die. Larvae develop to infective L3 in the egg in as short as 3-5 days. Horses are infected when they ingest **eggs containing L3**. The worms mature to adults around 45-60 days after infection. There has been an increase in pinworm reports in the UK. It is not clear if this is due to animals being treated inappropriately, dewormers not working effectively due to a lack of access of active dewormer to worms at the rectum or skin, dewormer resistance, increased survival of eggs in the environment or more awareness by owners. Key to control is to **remove eggs from the environment** by disinfecting and rinsing *all* areas where an infected animal may rub (i.e. gates, fence posts, troughs etc.). If a horse or pony is identified as persistently affected, advice on treatment should be sought directly from a veterinary surgeon.

Parascaris equorum

P. equorum adults are found in the small intestine. These are thick creamy white worms that resemble noodles (female adult worms reach 38 cm in length). Females lay eggs, which are excreted in dung. Eggs develop to contain infective larvae (see life cycle below).

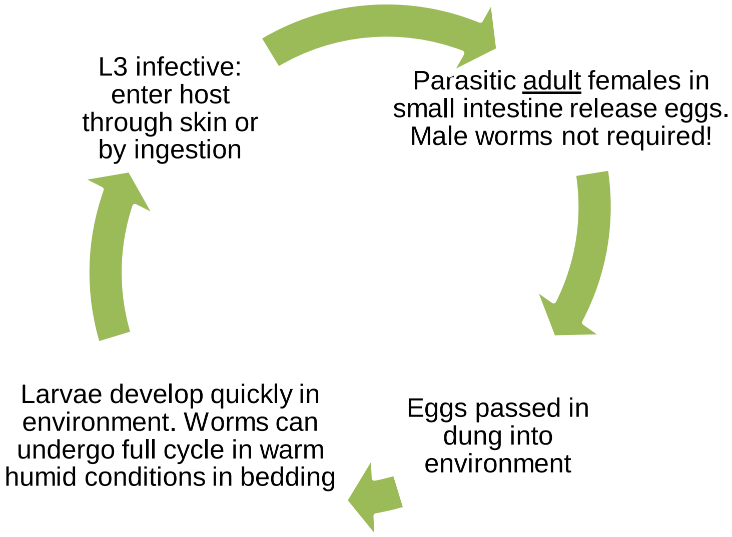


Development to the infective stage takes approximately 10 days at temperatures of 25°C to 35°C. Once eggs are ingested, larvae hatch in the intestine and migrate to the liver, then the lungs. Migrating larvae reach the lungs ~7 days after infection. They migrate through the lungs before being coughed up and swallowed ~4 weeks after infection. In the intestine, they develop to adult worms. Eggs are usually excreted around 10 weeks after infection.

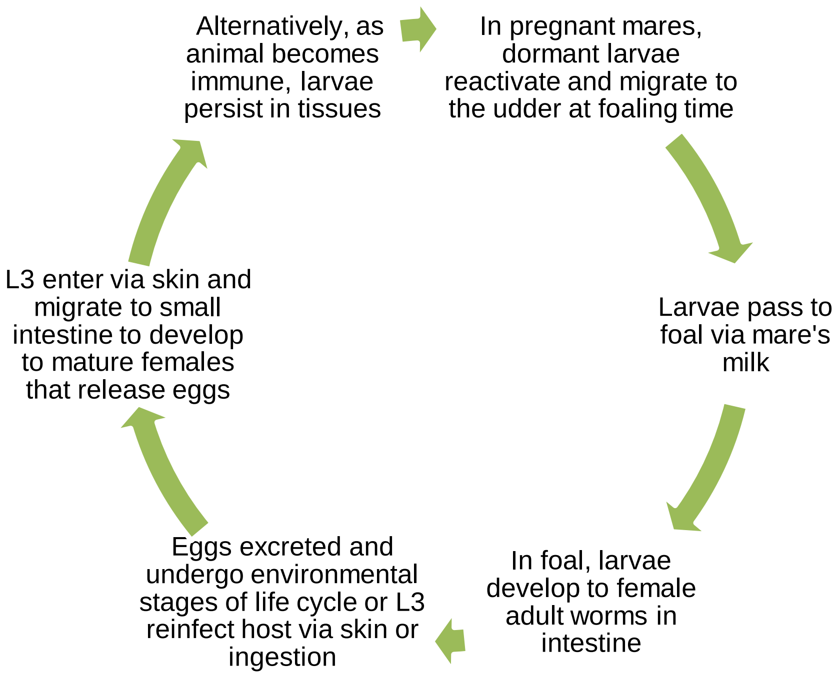
This is a common important parasite of foals and yearlings. It is unusual to see ascarid problems in adult horses because most horses develop immunity. The majority develop immunity in the first year of life, so infections (i.e. detection of *P. equorum* eggs in dung) are rarely diagnosed in horses more than two years of age. The principal source of infection for foals are pastures, paddocks, or stables contaminated with eggs from foals of the previous year. The larvated eggs have been reported to survive in the environment for up to 5-10 years. High levels of infection can cause nasal discharge and coughing as well weight loss and poor coat condition. In severe infections, youngsters can develop colic which may be fatal. If *P. equorum* infection is suspected in foals or yearlings, advice on treatment should be sought directly from a veterinary surgeon.

Strongyloides westeri

This small threadworm has an unusual life cycle , with development through all worm stages able to occur in the environment.



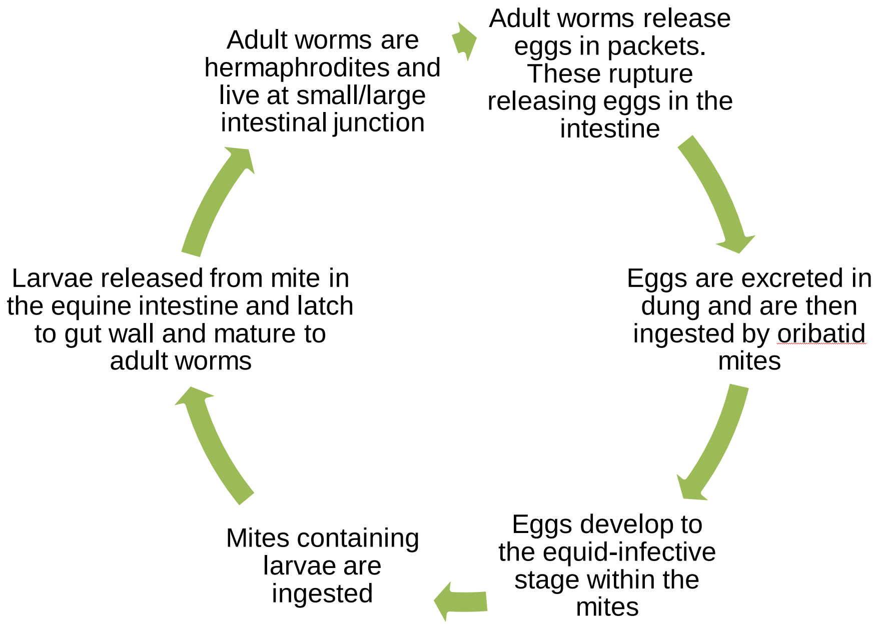
In this cycle, eggs hatch in bedding and, in warm humid conditions, worms develop to males and females, which produce eggs. Alternatively, when conditions are not conducive to environmental survival and/or when permissive hosts are present, infective L3 infect via the skin or by ingestion. The larvae migrate from skin to the intestine and, here, female worms reproduce asexually to release eggs. The eggs are excreted in dung. As horses develop immunity, *S. westeri* larvae that migrate from skin can enter host tissues and undergo 'dormancy'. Dormant larvae can commence development in pregnant mares to be transmitted to foals via **milk**.



Most serious infections arise from milk infection, with signs of diarrhoea in young foals. Dermatitis of the lower limb/coronary band can occur under high levels of challenge, common when bedding is not changed regularly. High levels of infection and clinical signs are rare in animals over 6 months.

b. Tapeworms

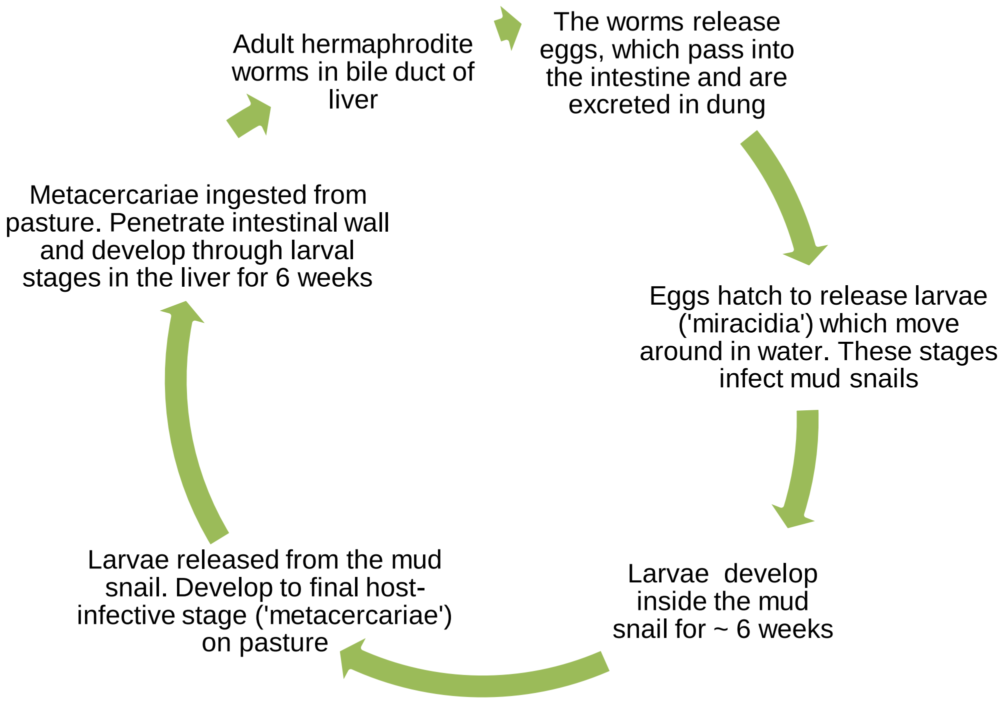
Anoplocephala perfoliata is the commonest tapeworm. Adult worms are hermaphrodite and found at the junction of the small and large intestine. These are 4-8 cm long and resemble flattened, shell-shaped pasta. Infection has been linked to intestinal blocking and colic. Individuals with high burdens are more likely to develop clinical signs. Unlike roundworms above, the tapeworm life cycle (below) involves **two hosts**; an intermediate host (**an oribatid mite**) and a final host (an equid).



The period from infection with the cyst in the mite to excretion of eggs is 6-10 weeks. Adult tapeworms produce large numbers of eggs over their lifetime. Most horses **have relatively few tapeworms** and do not develop disease.

c. Liver fluke

Liver fluke (*Fasciola hepatica*) infection is less common in horses and is more common in cattle and sheep. Adult worms are hermaphrodite and live in the bile ducts of the liver where they cause damage. The worms are 2-3 cm long and are flat, leaf-shaped and pale brown. Unlike the other worms listed here, liver fluke has a **broad host range**. Horses on pasture previously grazed by ruminants or grazing concurrently with ruminants are most at risk of infection; however, liver fluke can be carried by rivers or heavy rain run-off, so infection can occur where there is no direct co-grazing with ruminants. The infective stages are found in wet marshy areas. This is because liver fluke requires a **mud snail intermediate host** to complete its life cycle (below).



Liver fluke can be difficult to diagnose in horses as the clinical signs are not specific.

Liver fluke can infect humans if they eat contaminated raw vegetables; humans cannot catch fluke directly from animals.

Sustainable worm control programmes

Important points to note in designing worm control programmes:

1. Instituting a control programme that prevents accumulation of large numbers of worms on pasture is key to limiting burdens in horses
2. Historically, control was based on regular administration of dewormers. Frequent treatments have led to dewormer resistance
3. Worm control programmes must address the threat of resistance and dewormers must be used responsibly

3. Dewormers (anthelmintics)

Most dewormers are 'broad-spectrum', meaning that effective against several worm types.

Listed here, are the dewormer 'classes' licenced for use in equids in the UK.

Class 1. benzimidazoles (includes **fenbendazole**; for roundworms only)

Class 2. tetrahydropyrimidines (includes **pyrantel**; used for roundworms and for tapeworm, when administered at twice the dose used for roundworm treatment),

Class 3. macrocyclic lactones (includes **ivermectin** or **moxidectin**; roundworms only).

A further class, the isoquinoline pyrazines (includes **praziquantel**) is used for the treatment of tapeworms, including *A. perfoliata*.

Some products contain two classes; for example, ivermectin or moxidectin for roundworm treatment combined with praziquantel for tapeworm treatment.

All dewormers are classified as **POM-VPS** veterinary medicines in the UK, meaning that they can be purchased from a veterinary surgeon, a Suitable Qualified Person or a veterinary pharmacist. In all cases, a **discussion** on **treatment options**, **integration** of treatments with **environmental control methods** and the use of **diagnostics** to guide treatment decisions should be held with the prescriber *before* purchase. Generally, dewormers with label claims against strongyles are effective against egg-laying adult worms, but only some products are effective against migrating large strongyle larvae or small strongyle encysted larvae in the gut wall. Table 2 highlights the spectrum of activity of the different types of dewormers.

Table 3. A summary of dewormer spectrum of activity against different worm species.

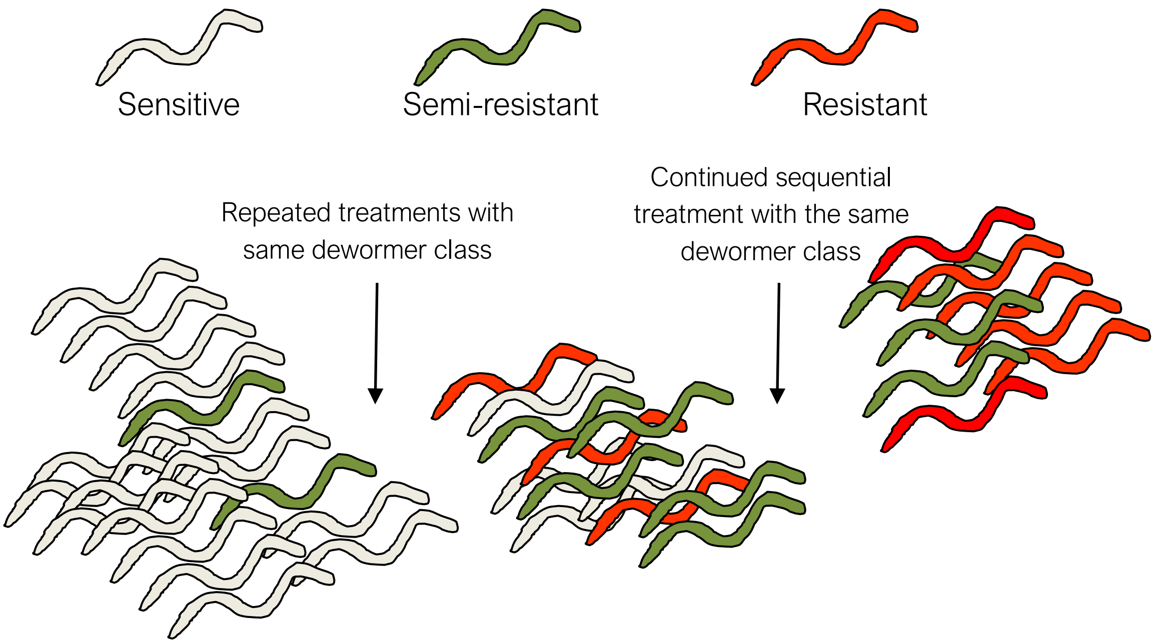
Active ingredient (class of dewormer)	Dewormer demonstrated to be active against…..
Fenbendazole (class: benzimidazole) Note: high fenbendazole resistance levels in small strongyles in UK and other regions	**Single dose** Adult small strongyles Adult large strongyles, *S. vulgaris* and related species, *Strongylus edentatus*. Adult and immature *Oxyuris* spp., *Strongyloides* spp., *P. equorum* (<u>not</u> migrating larvae in lungs) **Five consecutive daily doses** In addition to the above activity: Small strongyle EL3, LL3, DL4 Migrating larval stages of *S. vulgaris* and tissue stages of *S. edentatus* Migrating larval stages of *P. equorum.*
Pyrantel embonate (class: tetrahydropyrimidine)	**Single dose** Small strongyle adult worms Large strongyle (*Strongylus* spp.*)* adult worms *O. equi* adult worms *P. equorum* adult worms **Double dose** *A. perfoliata* adult worms
Ivermectin (class: macrocyclic lactone)	Small strongyle adult worms and L4 (not EL3) *S. vulgaris* adult and arterial larval stages *S. edentatus* - adult and tissue larval stages *S. equinus* and other large strongyle adult worms *Dictyocaulus arnfieldi* (lungworm) - adults and larvae *O. equi* adult and immature worms *P. equorum* adult worms, L3 and L4 *S. westeri* adult worms Bots: oral and stomach stages
Moxidectin (class: macrocyclic lactone)	Small strongyle adult worms, luminal larval stages and gut wall encysted larval stages, including EL3 *S. vulgaris* adult and arterial larval stages. *S. edentatus* adult and tissue stages, and adult worms of other large strongyle spp. *P. equorum* adult and larval stages *O. equi* adult and larval stages *S. westeri* adult stages Adult stages of other less common stomach worms Bots: oral and stomach stages
Praziquantel (class: Isoquinoline pyrazine)	*A. perfoliata* adult worms (as combination product, Pramox, label claim also for adult worms of less common tapeworm spp.)

Please note that brand names are not included here; some dewormers exist as many generic forms. Ensure that you know which dewormer ingredients are present in the brand used. If in doubt, ask your prescriber.

Note that for some combination products the label claims and safety data may be different from the products marketed as single dewormers. Always read the label claims and safety information as defined for each product on the packaging. If in doubt, ask your prescriber.

4. Dewormer resistance

Resistance develops when worms are able to survive a dewormer treatment that was previously effective. Drug resistance arises through changes (mutations) in worm DNA. These mutations cause an alteration in worm proteins that are targets of the dewormer itself or proteins that help worms withstand the presence of the dewormer. The mutations are **passed from one worm generation to the next**, so with repeated treatments with the same dewormer, the proportion of worms that contain the mutations increases. This cartoon depicts how resistance develops.



The most serious consequence of resistance is **complete treatment failure**, meaning that a particular dewormer is no longer effective leading to persistent infection and, if high worm burdens develop, clinical disease. **Resistance (reduced efficacy) has been reported for all roundworm dewormers**:

- fenbendazole
- pyrantel

- ivermectin
- moxidectin.

Table 3 summarises global reports of resistance in common worm species.

Table 3. A summary of dewormer resistance in published reports globally.

Dewormer type	Small strongyles	*S. vulgaris*	*P. equorum*	*O. equi*	*A. perfoliata*
Fenbendazole	+++	-	+	+	n/a
Pyrantel	++	-	+	+	-
Ivermectin	+	-	+++	+	n/a
Moxidectin	+	-	+	+	n/a
Praziquantel	n/a	n/a	n/a	n/a	-

+ early indications of resistance based on published worm egg reappearance period studies or resistance/lack of efficacy reported anecdotally
++ resistance reported in some regions and published reports indicate levels are moderate
+++ resistance reported in many regions and published reports indicate resistance widespread
- resistance not yet reported
n/a dewormer resistance not applicable that worm species

Dewormer resistance is **irreversible**.

Resistance to one dewormer type or in one worm species does not mean that there will be resistance to the same dewormer in a different species; however, cross-resistance (resistance in one type of worm against two types of dewormer) occurs and resistance is most likely between two dewormers in the same anthelmintic class.

Dewormer resistance is **common in small strongyles**, particularly to **fenbendazole**. Small strongyle populations resistant to fenbendazole and pyrantel have been reported in 14 and 12 countries, respectively, including the UK. Small strongyle resistance to **ivermectin** and **moxidectin** was reported in Brazil. Resistance to **ivermectin** and **moxidectin** is suspected in several countries, where a **shortened egg reappearance period** (see below) was reported after treatment.

***P. equorum* resistance** to **ivermectin** has been reported in several countries, including the UK. There are also reports of **pyrantel** resistance in *P. equorum* in the USA and to **fenbendazole** in Australia.

There are many anecdotal reports of **macrocyclic lactone** (ivermectin, moxidectin) resistance in **pinworm**, but no published research reports. It is difficult to assess dewormer resistance in pinworms (see below).

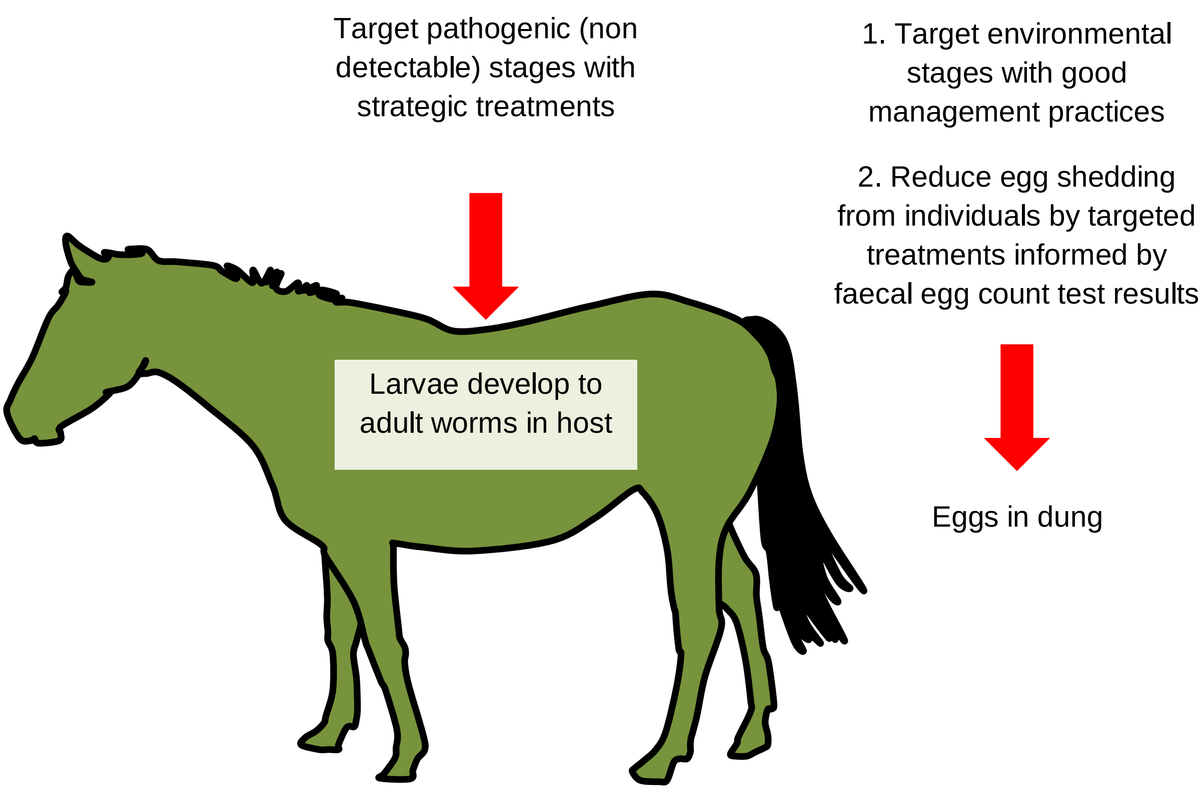
There are no published research reports of dewormer resistance in large strongyle species, in *S. westeri* or in *A. perfoliata*.

5. Sustainable control programmes

The main objective of control is to limit levels of infection so that horses remain healthy and clinical disease does not develop. It is important to **target**:

1. worm contamination on pasture by removing egg-containing dung and/or dewormer treating animals that shed high numbers of eggs
2. immature and adult worms inside the host by applying strategic treatments.

This cartoon summarises this approach.

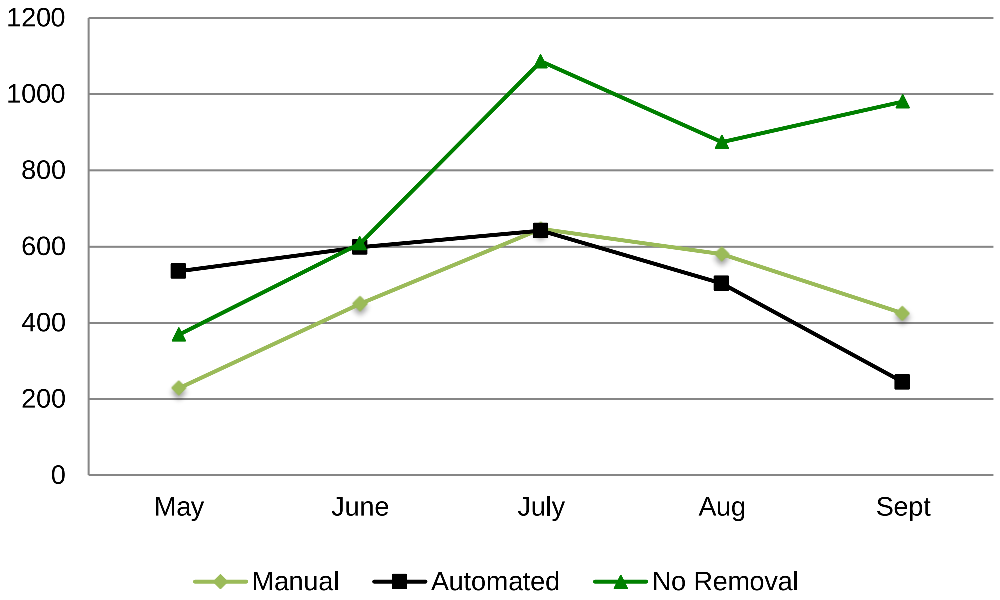


Frequent treatments should be avoided since this promotes dewormer resistance. It is impossible to eradicate all parasites from all animals and trying to do so only selects for resistance.

All control strategies must include good pasture management to reduce worm infection levels in the environment.

Dung removal should be performed to break worm life cycles and reduce pasture contamination. This should be done at intervals that prevent movement of L3 from dung onto grass. In the UK, the recommendation is to remove dung at least twice-weekly in summer. The graph below demonstrates the effect of dung removal on subsequent worm egg shedding of grazing donkeys.

Mean faecal egg count per group (strongyle eggs per gram)



Adapted from: Corbett CJ, Love S, Moore A, Burden FA, Matthews JB, Denwood MJ. The effectiveness of faecal removal methods of pasture management to control the cyathostomin burden of donkeys. Parasit Vectors. 2014 Jan 24;7:48.

This study at the UK Donkey Sanctuary (Devon), demonstrated significant differences in worm egg shedding (mean FEC/group, y-axis) over the season when comparing equids on pastures with no dung removal ('No Removal') to those on pastures subjected to automated ('Automated') or manual ('Manual') dung removal.

In addition to removing dung, or where it is not logistically possible to do it regularly, **pastures should not be overgrazed**. A general rule is to graze at 1 horse per 1-2 acres (0.4-0.8 hectares).

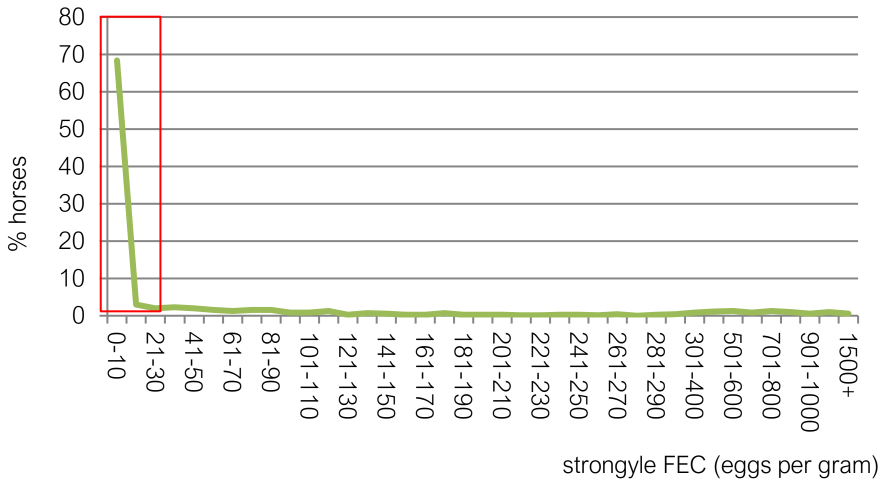
Resting pastures is recommended. Pastures should be rested long enough to allow significant reductions in contaminating larvae. Strongyle L3 can survive a few weeks in hot weather, but 6-9 months in cooler weather. Thus, season and local weather conditions must be considered when calculating how long pastures should be rested for before deemed 'safe'. Another approach is to alternate and/or practice **mixed grazing** with cattle or sheep. A worm species that lives in the stomach (*Trichostrongylus axei*) is capable of infecting cattle, sheep, pigs *and* horses, but is not considered a clinical threat. Liver fluke can cross between hosts if pastures include areas where mud snails can live. If concerned about fluke, tests can be performed to detect egg shedding in ruminants and, where infection is suspected, testing can be performed in horses (see below).

Harrowing is cited as a tool to reduce pasture contamination. Depending on weather conditions, harrowing can increase contamination by breaking dung and spreading larvae across grazing. If dry hot conditions prevail, larvae die in a few weeks, but if such conditions are not encountered, L3 survive for months. If harrowing is practiced, pasture should be rested until considered safe; this depends on weather conditions. In the UK, it is suggested that harrowed pastures not be grazed in the same season.

Targeting treatments using Faecal Egg Count testing

Why use Faecal Egg Count tests to support worm control?

Faecal Egg Count (FEC) directed treatment protocols work well in horses because worm egg shedding is unevenly distributed among individuals. In groups of adult horses, usually ~20% of individuals shed ~80% worm eggs at any given time. This is demonstrated below in a chart of strongyle FEC shedding patterns of ~ 1,200 horses. Note that the majority of horses have negative or low FECs (in the red box).



Adapted from: Relf VE, Morgan ER, Hodgkinson JE, Matthews JB. Helminth egg excretion with regard to age, gender and management practices on UK Thoroughbred studs. Parasitology. 2013 Apr;140:641-52

In FEC directed treatment protocols, horses identified as **shedding strongyle egg levels above a threshold** (for example, 200 eggs per gram, EPG), are recommended for dewormer **treatment**. **FEC-negative or low egg shedders** (i.e. those that shed < 200 EPG) are left **untreated**. The horses are FEC tested again at a defined interval, which is determined by the type of stock (young *versus* adult), the type of management and the dewormer administered.

FEC directed treatment protocols are designed to **reduce dewormer treatments applied**, hence, **lowering selection pressure for resistance**, and at the same time, have **a significant impact on the number of eggs shed into the environment**.

When compared to traditional 'all-group' dewormer treatments, FEC-directed treatment protocols can be financially beneficial. One UK analysis of 14 yards showed that dewormer administration was reduced by 82% on the basis of FEC test results (treating at a 200 EPG threshold). Taking into account the cost of FEC testing (based on an average charge of several FEC service providers), a mean saving of £294/year per yard was calculated compared to a programme where interval treatments with moxidectin were applied.

What do FEC tests tell us?

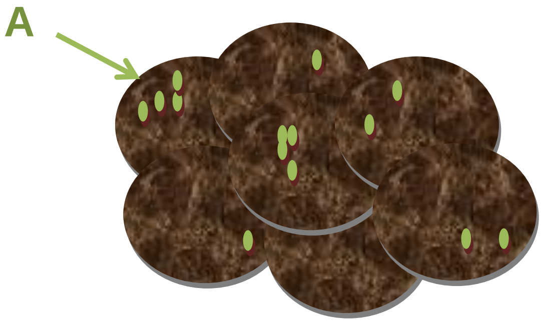
FEC tests provide information on:

i. Worm egg shedding levels by individual horses, which provides information for targeting dewormer treatments at certain times of year
ii. The types of worm egg that a horse is shedding
iii. The effectiveness of dewormers (see below).

FEC tests estimate the number of **worm eggs per gram in dung**. There are several methods available. These all work on the same principle of taking a proportion of dung, cleaning it up, separating out worm eggs (usually by flotation in salt solution) and counting the worm eggs under a microscope. Some tests have higher sensitivity than others; the higher the sensitivity, the more valuable the information the test provides. It is recommended that a FEC test service that offers a method with **high sensitivity** is selected (ask your service provider about the sensitivity of their test).

Sampling

Worms eggs are not evenly distributed in dung. This cartoon depicts how worm eggs can be spread across a heap. If ball A was sampled and counted, it would indicate a higher number of eggs than was representative of the entire sample.



Therefore, when obtaining a sample, ensure it is **representative** across the heap. For this reason, collect from 3-4 balls (or different parts of the heap), mix the sub-samples together, and collect at least 30 grams ('a good handful'). Because eggs hatch within a day or so, especially when it is warm, samples must be collected **fresh** and transported in a sealable container or bag. It is important to have **no air** in the container or bag, as air promotes egg hatching. Samples should be transported at a cool temperature to reduce hatching. All these principles apply at the laboratory too, in order to ensure that the final FEC count is representative.

Summary of guidelines for obtaining accurate FEC tests

1. Sample(s) should be collected from fresh dung (<12 hours-old)
2. A representative sample should be collected (~30-40 grams) including small quantities from different balls
3. Sample(s) should be stored in zip-lock bags, expelling all air before sealing and keeping refrigerated (~4°C) until taken or posted to the laboratory. A rapid registered delivery system is recommended if posting
4. Sample(s) should be processed 5 days from collection (the sooner the better)

The images here show types of worm eggs that can be detected in a dung sample.

This image shows a typical sample examined under a microscope. The two oval eggs are strongyle eggs and the single D-shaped egg below is a tapeworm egg. Tapeworm egg shedding can be intermittent and standard FEC tests are not sensitive for detecting these eggs. Other tests are available for *A. perfoliata* (see below).

The egg shown here is a *P. equorum* egg. These are most commonly seen in samples from foals and yearlings.

The eggs shown here are smaller. These are *S. westeri* eggs and are commonly found in young foals. They are only a clinical issue when found in very high numbers.

Large and small strongyle eggs cannot be distinguished in a FEC test. To determine if a horse is shedding large or small strongyles eggs, samples need to be processed to obtained L3, which are then examined to define worm type. This can be performed by specialist laboratories in the UK. If horses have received macrocyclic lactone treatments, most eggs detected are highly likely to be small strongyle eggs.

Standard FEC tests cannot detect liver fluke eggs. A different type of FEC test can be used to detect these in cases where there is infection with adult worms. A blood test is under study at Liverpool University (https://www.liverpool.ac.uk/testapet/test/). Owners who suspect infection should obtain advice from their veterinary surgeon. No anti-fluke dewormers are licenced for horses in the UK.

Detecting tapeworm infection

FEC testing does not accurately detect *A. perfoliata* infection. Alternative methods are commercially available to detect infection. These are; a blood test (https://www.liverpool.ac.uk/diagnosteq/diagnostic-tests/tapeworm-antibody-test/) and a saliva test (http://equisal.co.uk/The-Test). In both tests, samples are examined for the presence of **antibodies** specific to *A. perfoliata*. Both tests are accurate in detecting infection and provide information on likely exposure to *A. perfoliata.* Along with the correct information on clinical and treatment history, results from these tests can be used to inform on the need to apply anti-tapeworm treatments. Refer to the websites listed to ensure that appropriate sampling procedures are followed.

Detecting pinworm infection

The presence of pinworm can be detected using a '**tape' test**. Here, sticky tape is used to take an impression from skin under the horse's tail, where female pinworms come out and lay their eggs. The strip is examined under the microscope for the presence of pinworm eggs.

What to do about worm stages that cannot be detected using diagnostic tests?

Immature worm stages that do not produce eggs (strongyle and ascarid larvae) cannot be detected using FEC tests. Because these stages can cause serious disease when present in high numbers, **treatments should be applied that target larval stages**.

For **small strongyle encysted larvae**, the current recommendation in the UK is to deliver a **'larvicidal' treatment in late autumn or winter**. Two types of dewormer are licensed for activity against these stages; **moxidectin** and fenbendazole (as a 5-day course). Given the high levels of fenbendazole resistance, moxidectin is recommended. Moxidectin will also kill large strongyle, ascarid and pinworm larvae, as well as adult worms of all roundworm species listed above, as well as bots.

This larvicidal treatment is recommended because there are no tests available to enable detection of large or small strongyle larvae that would inform requirement to treat. A blood test for identifying small strongyle infection is under development using funding from the Horse Trust. It is anticipated that this will be available by 2019.

There are specific recommendations for foals for targeting *P. equorum*. These are detailed below in Section 7 (Putting targeted deworming protocols into practice).

6. Testing for dewormer resistance

It is important to establish whether or not dewormers are effective. When treating with an effective dewormer, adult worms die and egg production stops. The faecal egg count reduction test (FECRT) is a tool for establishing how well dewormers work and is particularly useful for assessing the dewormer sensitivity of small strongyles. The test is generally a **herd test** and has limited application in individuals. To do the test, two dung samples are collected; the first on the day of treatment (day 0) and a second sample at 14-17 days after treatment (from animals measured as 200 EPG or over at day 0). Samples should be handled exactly as described for FEC testing (above). Strongyle egg count results before and after treatment are used to calculate the mean percentage reduction in eggs counted before and after treatment. The cut-off values for considering if a dewormer is effective are: a mean 95% reduction in FEC for ivermectin and moxidectin or a mean 90% reduction in FEC for fenbendazole and pyrantel. If the percentage FEC reduction after treatment is above these values, no further action is required. If the percentage reduction falls below the cut-offs, resistance is suspected. Owners who suspect that dewormers are not working, should speak to their veterinary surgeon and request a test be performed.

Dewormer effectiveness can be monitored through evaluating **strongyle egg reappearance period** (ERP). This is the period after treatment in which worm eggs should not be observed in dung or their numbers are lower than 10% of those counted at treatment. For all modern dewormers, the strongyle ERP values were established at the time the products were launched; it is these values that determine the intervals recommended in interval treatment programmes. The expected strongyle ERP for each dewormer type is shown below.

Dewormer	Minimum strongyle ERP that would indicate effectiveness
Fenbendazole	6-8 weeks*
Pyrantel	4-6 weeks*
Ivermectin	6-8 weeks*
Moxidectin	12.8 weeks*

*Recommended ERP/treatment interval as cited on the website of the UK Veterinary Medicines Directorate (http://www.vmd.defra.gov.uk/ProductInformationDatabase/) for fenbendazole (Panacur Equine Granules 22.2% w/w), pyrantel (Strongid - P Paste 43.90% w/w), ivermectin (EQVALAN Oral Paste for Horses) and moxidectin (EQUEST ORAL GEL, 18,92 mg/g, oral gel for horses and ponies).

A **short ERP** is thought to be an **early indicator of resistance**. ERP monitoring is advised for investigating effectiveness of **ivermectin** or **moxidectin**. This can be done by performing FEC tests every 2-3 weeks after treatment and identifying when the first positive FEC results after treatment occur or, using a conservative measure, until the mean FEC after treatment reaches 10% of the level counted at treatment. Although labour intensive, ERP monitoring is recommended where there has been high use of ivermectin or moxidectin or where an owner/veterinary surgeon suspects that dewormers are not working. If sample collection is not possible at regular intervals, then FEC testing can be performed on the week of the expected ERP (see above). A high FEC at this time in **several** individuals could indicate resistance and further testing using the FECRT is recommended. If a product is found to fail, further use is not recommended. In the UK, dewormer failures must be reported to the Veterinary Medicines Directorate at:

https://www.vmd.defra.gov.uk/adversereactionreporting/Product.aspx?SARType=Animal.

Shortened ERPs in small strongyle populations are becoming increasingly reported. A recent UK study calculated strongyle ERP after moxidectin treatment on eight yards and identified that the ERP was short on all but one yard. Reduced ERP has also been observed after ivermectin treatment in the UK. These data reflect results in other countries and are of concern given the high levels of resistance in small strongyles to fenbendazole and pyrantel. **These studies provide evidence of resistance in small strongyles to all three available classes of dewormers.**

7. Putting targeted deworming protocols into practice

The DOs and DON'Ts of Worm Control

1. DO seek advice from a veterinarian who can perform an informed risk assessment of likely worm infection levels.
2. DO use weight tapes or, preferably, weigh scales to determine body weight to ensure appropriate dosing. Under-dosing selects for dewormer resistance.
3. DO ensure that the full dose is swallowed. Under-dosing selects for dewormer resistance.
4. DO store dewormers according to the information on the packaging. Dosing with old or inappropriately stored products that do not work as well as they should selects for dewormer resistance.
5. DO ensure that all horses/ponies are on the same deworming programme.
6. DO use dung removal as a method of environmental worm control – lift dung at least twice a week.
7. DO quarantine all new horses. Administer moxidectin/praziquantel, withhold from pasture for 72 hours, and perform a faecal egg count test 2 weeks after treatment to check that the product has been effective in reducing egg shedding.
8. DO NOT dose then move to clean pasture - this selects for dewormer resistance.
9. DO NOT use anti-parasitic products not specified for use in equids – they may be toxic. Dosing with inappropriate products that do not work as well as they should also selects for dewormer resistance.

Owners should always have a detailed discussion with their prescriber before purchasing a dewormer to decide if a treatment is necessary and, if so, which product should be selected. A **risk assessment** of likely worm transmission should be performed, taking into account the resident population, grazing management, history of dewormer use, clinical history and results of any diagnostics performed.

Below are some outline recommendations for sustainable worm control programmes, based on animal age. These are based on UK seasons.

Adult horses

i. Apply **FEC-directed treatments** spring till late autumn. Pyrantel or ivermectin are currently recommended for FEC-directed treatments. Use an EPG threshold of 200 EPG* for horses on well-managed pastures where dung is lifted regularly.
ii. The interval for follow-up FEC testing should be 6-8 weeks after pyrantel or 8-10 weeks after ivermectin treatment (calculated from the 'expected' ERP + 2-3 weeks).
iii. A **FECRT** should be included each year to test dewormer effectiveness, especially if pyrantel is administered.
iv. Depending on risk of *A. perfoliata* transmission, blood or saliva tapeworm tests should be carried out in spring and/or autumn. Tapeworm-positive animals should be treated with praziquantel or pyrantel (twice the dose recommended for roundworms). If tapeworm tests are not performed, a single annual tapeworm treatment with praziquantel** should be administered.
v. **All equids should be administered with moxidectin*** in autumn**. This should be applied at least 4-6 weeks after the last pyrantel or 6-8 weeks after the last ivermectin treatment.
vi. FEC testing should be performed 12-14 weeks after moxidectin treatment to monitor egg shedding in late winter/early spring, especially if horses are grazing parts/all day and the weather is mild. This will inform on the need for further treatment.

Good pasture management, especially dung removal, should be performed to reduce contamination of pasture with worms

* EPG threshold for treatment should be adapted on a case-by-case basis depending on a risk assessment of the level of environmental contamination and class of stock. No guidelines are published for the acceptable number of *P. equorum* eggs for treatment thresholds; if these are detected (more likely in horses 2 years-old and under), treatment is recommended.
** Praziquantel treatment recommended in autumn, rather than pyrantel at the double dose.
*** Most anthelmintics do not have high efficacy against small strongyle early third stage larvae. Five-day fenbendazole treatment has licensed efficacy against these stages, but resistance is almost ubiquitous in small strongyles in developed regions.

A FEC-directed treatment programme can be used for animals of **1-2 years-old**; however, there are features that should be taken into account and the programme should be developed under supervision of a veterinarian. First, the recommended FEC testing interval is **shorter** than for older horses. This is because younger horses usually shed higher levels of strongyle eggs and tend to have a shorter ERP after treatment. Second, after an all-group moxidectin treatment in autumn, a second moxidectin treatment may be necessary 12-14 weeks later. Application of this second treatment should be based on results of FEC testing and on risk assessment of the likely levels of contamination on grazing in the intervening period.

1-2 year-olds

i. Apply **FEC-directed treatments** spring till late autumn. Pyrantel or ivermectin are currently recommended for FEC-directed treatments. Use an EPG threshold of 200 EPG* for horses on well-managed pastures where dung is lifted regularly
ii. This group is more likely to have higher burdens than adults and hence shed higher levels of eggs. The interval for follow-up FEC testing should be 4-6 weeks after pyrantel treatment or 6-8 weeks after ivermectin treatment.
iii. A **FECRT** should be included each year to test dewormer effectiveness, especially if pyrantel is administered.
iv. Depending on risk of *A. perfoliata* transmission, blood or saliva tapeworm tests should be carried out in spring and/or autumn. Tapeworm-positive animals should be treated with praziquantel or pyrantel (twice the dose recommended for roundworms). If tapeworm tests are not performed, a single annual tapeworm treatment with praziquantel** should be administered.
v. **All equids should be administered with moxidectin*** in autumn**. A second moxidectin treatment may be necessary 12-14 weeks later, based on the results of FEC analysis and a risk assessment of likely levels of contamination on pasture. Youngsters are more likely to require a second treatment if they are grazing outside in mild winters, especially if grazed at high stocking density on paddocks not subject to regular pasture hygiene.

Good pasture management, especially dung removal, should be prioritised on pastures grazed by young horses. Avoid using paddocks for young horses year after year; rest and rotate where possible.

* EPG threshold for treatment should be adapted on a case-by-case basis depending on a risk assessment of the level of environmental contamination and class of stock. No guidelines are published for the acceptable number of *P. equorum* eggs for treatment thresholds; if these are detected (more likely in horses 2 years-old and under), treatment is recommended.
** Praziquantel treatment recommended in autumn, rather than pyrantel at the double dose.
*** Most anthelmintics do not have high efficacy against small strongyle early third stage larvae. Five-day fenbendazole treatment has licensed efficacy against these stages, but resistance is almost ubiquitous in small strongyles in developed regions.

Worm control programmes for **foals** are complex because of the different types of worm species that may be present. It is recommended that stud farms develop a worm control programme under the supervision of their veterinary surgeon.

The routine treatment of young foals for *S. westeri* is not recommended unless the parasite is identified as a clinical problem. A widespread practice is to deworm mares with ivermectin before foaling; however, if mares have been treated in the previous 6 months with moxidectin or ivermectin, there is little justification for this treatment.

The main focus for worm control in foals is ***Parascaris***. Larvae of this worm can cause disease and there are no diagnostic tests to detect these stages. As a result, dewormer treatments at 2-3 months (during the migratory phase) and 5-6 months of age are advised, especially on large farms where the risk of infection may be higher. Because of reports of ivermectin resistance, a benzimidazole is recommended for these treatments to try ensure effectiveness against *Parascaris*. FEC tests can be performed at the second treatment at 6 months to identify if foals are shedding eggs. A FECRT should then be performed by FEC testing worm egg-positive foals 2 weeks after treatment. If the FECRT indicates low efficacy, pyrantel can be used and subsequently tested for effectiveness. Alternatively, where ivermectin is known to be effective (by previous FECRT), it can be used for these treatments.

FEC testing can be performed in foals of 7-8 months to identify what worms should be targeted (*Parascaris,* strongyles or both). Ideally, a FECRT should be performed 2 weeks after treatment in foals that were egg-positive at treatment to check that the product has reduced FECs appropriately. Alternatively, if foals are 7-8 months by late autumn-early winter, then an all-group treatment with moxidectin should be administered. Moxidectin can be toxic in young foals, so read the product datasheets or Summary of Product Characteristics to check the lower age limit for moxidectin administration. A tapeworm test can be performed, and foals treated according to the result. Alternatively an anti-tapeworm treatment can be administered. Recently weaned foals should be turned out onto the cleanest pastures with the lowest levels of worm contamination.

Foals

i. **Seek veterinary advice** as dewormers selected will depend on a risk assessment of likely contamination levels and previous product use. Administer dewormer at 2-3 months-old *and* at 5-6 months-old. Options are fenbendazole, pyrantel or ivermectin*. Where possible apply FECRTs to check if dewormers are effective.
ii. Depending on the last treatment applied, FEC test** foals between 7 and 8 months-old to identify if treatment should be directed against a. *Parascaris* (treat FEC-positive foals with benzimidazole), b. strongyles (treat FEC-positive foals with ivermectin or moxidectin) or c. both types of worm eggs (treat FEC-positive foals with ivermectin [if *P. equorum* population ivermectin-sensitive] or pyrantel). A 2-week FECRT should be performed to ensure that the product is effective.
iii. If foals are 7-8 months in late autumn/early winter, treat with moxidectin***.
iv. Foals can be tested (blood or saliva ELISA) for tapeworm from 6 months on. Tapeworm-positive foals should be treated with praziquantel or pyrantel (at twice the dose recommended for roundworms). If tapeworm tests are not performed, a single treatment with praziquantel can be administered in autumn.

Optimal pasture management and dung removal should be prioritised on foal pastures.

Recently weaned foals should be turned out on grazing that is likely to have the lowest risk of infection.

Maintaining foals on the same pasture year-after-year is not recommended.

* Ivermectin resistance in *Parascaris* spp. has been reported in several countries.
** EPG threshold for treatment should be adapted on a case-by-case basis depending on a risk assessment of the level of environmental contamination and class of stock. No guidelines are published for the acceptable number of *P. equorum* eggs for treatment thresholds; if these are detected (more likely in horses 2 years-old and under), treatment is recommended.
*** Most anthelmintics do not have high efficacy against small strongyle early third stage larvae. Five-day fenbendazole treatment has licensed efficacy against these stages, but resistance is almost ubiquitous in small strongyles in developed regions. **Moxidectin can only be used in foals above 4 or 6.5 months, depending on the brand administered, so check the datasheet for specific detail.**

8. Recommendations for quarantine treatment

New acquisitions that will graze with permanent residents should be treated with moxidectin (+/- praziquantel or tapeworm test performed as detailed above) and kept off pasture, for three days. A post-treatment FECRT should be performed 14-17 days after treatment to examine the effectiveness of moxidectin.

Acknowledgements

The authors thank the Horse Trust for generously supporting their research and for supporting development of these guidelines.

The authors thank Dr. Hamish McWilliam (University of Melbourne) for graphics used in the guidelines and Dr. Wendy Talbot (Zoetis, UK) for comments in drafting the guidelines.

Further information

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