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A survey of the level of horse owner uptake of evidence-based anthelmintic treatment protocols for equine helminth control in the UK

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Abstract

Interval treatment control programmes used widely in equine helminth control have favoured the development of anthelmintic resistance worldwide. Best practice guidelines have been designed to address resistance and include the requirement for improved pasture hygiene to break helminth transmission cycles, along with anthelmintic application informed by the results of diagnostic tests to reduce selection pressure for resistance. Using an online questionnaire, this study examined uptake of measures recommended in these guidelines by UK horse owners. The survey comprised 58 questions spanning grazing management, anthelmintic use and use of faecal egg count (FEC) testing to inform treatment decisions. Analysis was carried out using a combination of Chi-square and Mann-Whitney tests. In total, 705 owners responded and, following specific exclusion criteria, the responses of 652 individuals were analysed. The majority of the respondents owned <20 horses on private premises or livery yards in England. The main outputs of the survey were as follows. Overall, 60.9% of respondents used FEC tests to inform the requirement to administer anthelmintics, with macrocyclic lactones the most frequently-used anthelmintics. Of the respondents, 38% obtained advice on anthelmintic choice from their veterinarians; however, many respondents (43.8%) purchased anthelmintics via the internet. Encouragingly, 74.4% of respondents stated that they practiced good pasture hygiene by removing dung from pasture. Generally, there were differences between the responses of participants who based anthelmintic treatments on FEC testing (targeted treatments; TT) and those who practiced calendar-based anthelmintic treatments (interval treatments; IT). Briefly, the “key” findings from the Chi-square analysis included higher levels of satisfaction with the level of knowledge about equine parasites/parasitic diseases and higher levels of concern about anthelmintic resistance from TT-respondents compared to IT-participants. Confusion on the interpretation of quarantine recommendations was identified in this study group and there was poor uptake of testing for anthelmintic effectiveness. Overall, compared to previous reports, this study indicated improved engagement of UK horse owners with some helminth control practices recommended to reduce the spread of anthelmintic resistance. However, a proportion of respondents did not utilise these practices and there were still important gaps in the use of appropriate quarantine and efficacy testing. These identified gaps must be taken into consideration in knowledge dissemination activities in the future.

Keywords: helminths; equine; questionnaire; anthelmintics; anthelmintic resistance; faecal egg count tests.

1. Introduction

Broad spectrum anthelmintics have been used for over 50 years for controlling equine helminth infections. A popular approach has been to administer anthelmintics to all animals within a group using interval treatment protocols, introduced in the 1960s following studies which sought to control the pathogenic nematode, *Strongylus vulgaris* (Drudge and Lyons, 1966). Over the years, the widespread use of interval treatment protocols has led to substantial reductions in *S. vulgaris*-associated disease; however, it has promoted development of anthelmintic resistance, particularly in the highly prevalent cyathostomin group of nematodes [reviewed by (Kaplan, 2002; Kaplan and Nielsen, 2010; von Samson-Himmelstjerna, 2012; Matthews, 2014; Peregrine et al., 2014; Tzelos and Matthews, 2016)]. Resistance to benzimidazoles and tetrahydropyrimidines, as measured by faecal egg count reduction test (FECRT), is widespread in cyathostomin populations worldwide (Matthews, 2014; Peregrine et al., 2014). Apart from one study in Brazil (Canever et al., 2013) and one in UK donkeys (McArthur et al., 2015), published reports of macrocyclic lactone effectiveness assessed by FECRT have indicated acceptable efficacy against cyathostomins at two weeks after treatment (Traversa et al., 2009; Relf et al., 2014). However, shortened strongyle egg reappearance periods (ERP) after ivermectin and moxidectin treatments has been reported in several countries (von Samson-Himmelstjerna et al., 2007; Rossano et al., 2010; Lyons et al., 2011; Geurden et al., 2014; Relf et al., 2014; van Doorn et al., 2014; Tzelos et al., 2017). A shortened ERP is considered as an early indicator of resistance (Sangster, 2001). Although ivermectin and moxidectin appear effective in terms of reducing egg shedding two weeks after treatment, these compounds may be less effective against larval and early-adult stages, which mature and produce eggs before the standard ERP (Lyons et al., 2009; Lyons et al., 2010; Lyons and Tolliver, 2013). Ivermectin resistance is also reported as widespread in *Parascaris equorum* (Reinemeyer, 2009).

Anthelmintic resistance is a major welfare threat, particularly to young animals which are more susceptible to life-threatening burdens of these parasites (Reid et al., 1995). It is therefore essential that anthelmintic potency is protected and that treatment applications be informed by diagnostic tests (Herd, 1993; Proudman and Matthews, 2000; Lester and Matthews, 2014; Nielsen et al., 2014a) and integrated with improved pasture hygiene practices such as dung removal to reduce infection levels in the environment (Herd, 1986; Corbett et al., 2014; Tzelos et al., 2017). Despite this approach being advocated for >20 years, surveys across different countries have indicated relatively low horse-owner uptake of the principals behind sustainable methods of helminth control (O'Meara and Mulcahy, 2002; Lind et al., 2007; Fritzen et al., 2010; Relf et al., 2012;

Nielsen et al., 2014b; Stratford et al., 2014; Bolwell et al., 2015; Robert et al., 2015; Salle and Cabaret, 2015; Rosanowski et al., 2016). In particular, the common finding in the aforementioned studies from 2002 to 2015 was the respondents' high levels of concern about anthelmintic resistance and the relatively low percentage of FEC testing before anthelmintic treatment (range among studies 0-50.6%).

There are nil survey-related studies in equine-parasitology in the UK published since 2014. The objective, here, was to assess if there was continued improvement in the uptake of evidence-based helminth control practices by horse owners, since there have been several industry-led initiatives promoting diagnostic-led treatment protocols to horse owners over the last decade; for example the Smart Worming Programme (http://www.smartworming.co.uk) and updated guidelines by the British Horse Society (www.bhs.org.uk/~/media/bhs/files/pdf-documents/worm-control.ashx). Furthermore, it is imperative to assess which practices still lack any uptake; for example, field assessment of anthelmintic efficacy, identified previously as not being implemented (Easton et al., 2016).

2. Materials and methods

2.1. Questionnaire format

A questionnaire was designed using previously published formats to assess equine helminth control measures (Relf et al., 2012; Stratford et al., 2014; Easton et al., 2016), in this case, utilizing the web-based software tool, (SurveyMonkey, https://www.surveymonkey.com/). The questionnaire comprised 58 questions divided into a 'Welcome' page with details about the project and requesting consent (n=1); 'General Information' (n=5) exploring demographic details of each respondent; 'Worms and Deworming' (n=29) assessing helminth control methods used and attitudes to parasites, treatment, advice and anthelmintic purchasing; 'Faecal Egg Counts' (n=6), which focused on respondent experience regarding FEC tests and anthelmintic efficacy testing; 'Worm Control in Foals' (n=2) and 'General Management' (n=12) which investigated additional approaches to helminth control such as the removal of faeces from pasture, stocking density levels and approaches to quarantine. A 'Future Studies' section (n=3) asked whether respondents would be willing to participate in future parasitological studies to assess helminth prevalence and anthelmintic efficacy. The 'Question Logic' function in SurveyMonkey was employed in some questions flows and respondents were directed in specific routes depending on their preceding answer. Most questions were of the closed multiple choice type. There were also open-ended questions and, in some cases, an opportunity for respondents to include additional comments. The questionnaire is included in Supplementary file 1. The survey was piloted using a small group of horse owners prior to distribution. These pilot survey results were not included in the analyses described below. Ethical approval was granted by the Senior Management Group of Moredun Research Institute when the project was approved for submission. All data were stored on a secure server at Moredun Research Institute, and backed up daily at an external site, with access limited to research project staff. Informed consent was obtained by respondents, and responses were anonymised prior to analysis.

2.2. Questionnaire distribution

The target population was UK individuals who manage and/or own equids. Responses were sought from stud farm and livery yard managers, riding school managers and owners who used livery yards or private premises. The questionnaire was available online for 13 weeks (13 April - 6 July 2015), and was primarily promoted via social media (mainly through posts on Facebook, https://www.facebook.com/). The questionnaire hyperlink was posted to equid-oriented groups on Facebook (n=10) with a short description of the project. A reminder was posted every 2 weeks. In addition, 384 equine practice email addresses were obtained from the British Equine Veterinary Association website (www.beva.org.uk). An email, detailing study background and an online link to the questionnaire was distributed to practices inviting them to promote the survey to clients via websites, social media and/or newsletters. A direct email was also sent to 518 equine premises, including riding schools and livery yards listed on the British Horse Society website (http://www.bhs.org.uk/professionals/become-bhs-approved/approved-livery-yards). The Horse Trust also promoted the survey on their website (http://www.horsetrust.org.uk/) and Facebook page.

2.3. Data analysis

In terms of selecting respondents to be included in the analysis, data were included when a respondent provided consent to participate (Question 1), had completed the 'General Information' section and provided a response to at least one question in 'Worms and Deworming' section. Respondent answers were then exported to Microsoft Excel (Microsoft Excel for Windows, 2010) and basic descriptive analysis performed in Microsoft Excel. Statistical analyses were carried out using Minitab 17 (Minitab® 17.1.0). Chi-square tests were performed for each question to determine whether the frequency of owners expressing agreement or disagreement with specific statements differed between those respondents that practiced 'interval treatment' (IT; i.e. calendar-based anthelmintic treatments of all animals in a group not informed by diagnostic [i.e. FEC] testing) *versus* 'targeted treatment' (TT; i.e. anthelmintic treatment of animals based on the results of diagnostic [i.e. FEC] tests) protocols. In particular, chi square tests examined whether respondents who followed targeted treatment (TT) protocols (n=397) answered specific questions differently to those that followed interval treatment (IT) protocols (n=161). Those respondents who stated that they followed a different type of protocol to the two stated above (94/652) were not included in this analysis. Due to testing of multiple comparisons (n=53), following correction via Šidák's formula (Sidak, 1967), values of $P \leq 0.0015$ were considered significant. For responses on a ranked (Likert) scale, significant chi-square results on a compressed scale (agree/disagree) were followed by Mann-Whitney tests across the full Likert scale.

3. Results

3.1. Demographic features of the study respondents

A total of 705 respondents clicked on the hyperlink, 652 of which were then included in the analysis. Of the latter, 519 respondents completed the survey, and 133 incomplete questionnaires fulfilled the inclusion requirements. Respondent distribution across the UK and general information on the respondents are presented in Table 1. Briefly, respondents were distributed as follows: England (73.5%; 479/652), Scotland (17.9%; 117/652), Wales (7.7%; 50/652) and N. Ireland (0.9%; 6/652). The largest proportion of respondents had accessed the survey after learning about it on social media (75.9%; 495/652), followed by direct email (13.5%; 88/652), ‘friend/colleague’ (8.3%; 54/652) and the Horse Trust website (2.3%; 15/652). A total of 92% respondents (600/652) stated that they were horse owners, 13.8% (90/652) were yard managers and 3.4% (22/652) were stud farm owners/managers (please note that respondents could chose more than one option here). A total of 8.7% (57/652) of respondents owned / managed ≥20 horses, 90.4% (589/652) managed/owned <20 horses and 0.9% (6/652) did not provide horse numbers. A total of 639 respondents stated they owned/managed at least one adult horse (>3 years-old), 120 respondents owned/managed at least one “youngster” (1-3 years-old) and 43 respondents stated they owned/managed at least one foal (<1 year-old). The majority of horses were kept on private premises (50.6%; 330/652), followed by livery yards (37.3%; 243/652), riding schools (3.4%; 18/652); livestock farms (2.9%; 19/652), multi-purpose stables (2.7%; 18/652), stud farms (2%; 13/652) and colleges/rescue centres (1.1%; 7/652).

3.2. Descriptive analysis of responses

An outline of the descriptive results is presented here and summary details for all survey questions are presented in Supplementary file 2. A FEC-directed TT regimens were followed by 60.9% respondents (397/652), whilst 24.7% (161/652) respondents stated that they used calendar-based IT regimens. A further 14.4% (94/652) respondents stated that they followed a "different type" of helminth control protocol, including "strategic" treatments (1-4 times/year) or "irregular" treatments (when they suspected worm infection). One respondent stated that they did not treat their horses with anthelmintics. Of the 395 respondents who stated that they followed a TT helminth control protocol, 54.9% (217/395) had moved from an IT protocol or "strategic deworming" programme in the previous 1-5 years, 24.6% (97/395) respondents had changed their type of helminth control to a TT one in the previous 5-10 years, 13.7% (54/395) in the previous year, 1.5% (3/395) stated that they did not know when they had made this change and 5.3% (21/395) stated they had always followed a TT programme. When asked who influenced them in changing their helminth control practice to a TT approach, 30.4% (120/395) of the respondents indicated that it was their veterinarian who had done so and 32.4% (128/395) stated that they were influenced by 'Other' factors, with the majority (26.3%; 104/395) stating that it was personal research via the internet, academic literature or magazines.

With regard to respondent opinions on their own level of knowledge of parasites/parasitic diseases, 37.5% (191/509) were 'neither satisfied nor dissatisfied', 27.1% (138/509) and 11.8% (60/509) were 'satisfied' and 'very satisfied' with their knowledge levels, respectively. The remaining 16.3% (83/509) and 7.3% (37/509) were 'dissatisfied' and 'very dissatisfied' with their knowledge of parasites and parasitic diseases, respectively. There was a high level of respondent recognition of worm species names listed in the survey. In order of importance, the helminths considered as key targets to treat were: small strongyles (38.7%; 197/509), *Anoplocephala perfoliata* (25.3%; 129/509), large strongyles (21%; 107/509), *Parascaris equorum* (5.1%; 26/509), *Fasciola hepatica* (1.6%; 8/509), *Oxyuris equi* (1.4%; 7/509) and *Gasterophilus intestinalis* (1%; 5/509). Regarding anthelmintic resistance, 32.2% (161/500) and 37.2% (186/500) of respondents were 'concerned' and 'very concerned' about this issue, respectively. Despite these levels of concern of anthelmintic resistance, 75.2% (376/500) respondents stated they were not aware of the anthelmintic sensitivity status of the worm populations on the premises where their horse(s) grazed.

Macrocyclic lactones were the most frequently used anthelmintics [ivermectin (42.5%; 197/463), moxidectin/praziquantel (35.6%; 165/463), ivermectin/praziquantel (35%; 162/463) and moxidectin (32%; 148/463)]. Use of other classes of anthelmintics was as follows:

fenbendazole as a single dose 5.2% (24/463) or a 5-day course 15.8% (73/463), pyrantel 17.7% (82/463) and praziquantel 22.5% (104/463) of respondents. A small proportion of respondents stated that they used "herbal products" (4.8%; 22/463). A total of 16% (74/463) of respondents were not familiar with the chemical names of anthelmintics specified in the survey. The majority of respondents stated that they "specifically targeted" tapeworm infections (77.3%; 358/463), with almost all respondents stating that they had used a product that contained praziquantel for tapeworm control. Over 60% (61.8%; 286/463) of respondents stated that they "specifically targeted" encysted stage cyathostomin infections with anthelmintic treatment. For small strongyles, 70.3% (201/286) respondents stated they targeted encysted larvae with a product containing moxidectin, 5.6% (16/286) five-day fenbendazole, 1.7% (5/286) ivermectin and 22.4% (64/286) stated that they did not know or followed their prescriber's advice for this type of treatment.

When selecting an anthelmintic, 38% (176/463) of respondents stated that they sought advice from a veterinarian, 19.2% (89/463) from a suitably qualified person (SQP), 16.8% (78/463) from a FEC service company, 4.8% (22/463) from an internet retailer, 1.5% (7/463) from a pharmacist, whilst 8.2% (38/463) of the respondents did not seek advice before purchasing an anthelmintic. When considering where thy purchased anthelmintics from, 20.7% (96/463) of respondents stated that they bought anthelmintics from same source from which they sought advice on anthelmintic selection. The highest proportion (43.8%; 203/463) of respondents stated they used an internet retailer for the purchase of anthelmintics. The remainder stated that they used a veterinarian (3.2%; 15/463), SQP (14.7%; 68/463) or pharmacist (3%; 14/463) for their anthelmintics purchase.

In the section pertaining to 'Worm control in foals', 76.2% (337/442) of respondents stated that they did not have foals at their premises. From the remaining 105 participants that answered this question, 66.7% (70/105) of respondents stated that they anthelmintic treated the foals at their premises. The remaining participants stated that they did not treat foals (21.9%; 23/105) or they did not know (11.4%; 12/105). On the question, "How does the deworming of foals compare to that of adult equines at your premises?", the respondents who anthelmintic treated foals stated: 'Same anthelmintic(s) are used, but different dosing regimen' (37.1%; 26/70); 'Different anthelmintic(s) are used' (22.9%; 16/70); 'Same protocol as in adults' (17.1%; 12/70); 'Other' (14.3%; 10/70); and, 'I do not know' (8.6%; 6/70).

With regards to general management (Supplementary file 2), 74.4% (392/527) of respondents stated that they practiced dung removal from pasture, 25% (132/527) did not remove dung and 0.6% (3/527) did not know whether this was applied at their premises. Additionally, 53.6% (210/392) of respondents that practiced dung removal from pasture stated that dung was removed daily and 31.4% (123/392) stated that it was removed every 2-7 days. The remainder stated that the frequency of dung removal was as follows: every 8-14 days (6.6%; 26/392), 15-28 days (4.1%; 16/392), less often (3.8%; 15/392) or do not know (0.5%; 2/392).

When asked whether new arrivals to the premises were treated with anthelmintics, 25.6% (137/535) of respondents stated that their premise was a closed yard, 9.5% (51/535) of respondents did not anthelmintic treat new arrivals and 6.5% (35/535) did not know what new arrivals were treated with. A total of 58.3% (312/535) of respondents stated they administered anthelmintic(s) to new arrivals with the preference for "quarantine treatment" as follows; moxidectin/praziquantel (25.9%; 81/312), ivermectin/praziquantel (20.1%; 63/312), a 5-day course fenbendazole (10.5%; 33/312), ivermectin (8.9%; 28/312), moxidectin (6.4%; 20/312), praziquantel (2.6%; 8/312), pyrantel (1.9%; 6/312), a single-dose of fenbendazole (1.9%; 6/312) and a "herbal product" (0.3%; 1/312). A total of 18.8% (59/312) of respondents did not know the anthelmintic used, 7% (22/312) did not recognize the chemical terms and 19.5% (61/312) selected "other", the majority stating that treatment depended on ‘FEC testing’, ‘advice from a prescriber’, ‘time of year’ and ‘last anthelmintic used’.

3.3. Chi-square and Mann-Whitney analyses of survey answers by respondents who reported using targeted treatment (TT) *versus* interval treatment (IT) protocols

In order to determine whether the frequency of owners expressing agreement or disagreement on specific aspects/views of helminth control differed between the groups categorized as respondents who followed a TT protocol and respondents who followed an IT protocol, Chi-square and Mann-Whitney tests were performed (see Supplementary files 3 and 4 for Chi-square and Mann-Whitney test results, respectively). In particular, for responses on a ranked or Likert scale, significant chi-square results were followed up with a Mann-Whitney test, and only those results that produced significant values using both tests are reported here. The P-values presented below are from the Chi-square tests, whilst the P-values from the Mann-Whitney tests can be found in Supplementary file 4.

Respondents who followed TT protocols were more likely to state that they were more ‘satisfied’ with their level of knowledge about equine parasites/parasitic diseases than those that used IT protocols (TT: 29.62%, 109/368; IT: 20%, 28/140; P=0.0002). Likewise, the TT group respondents were more likely to state that they were ‘very concerned’ about anthelmintic resistance than those who implemented an IT protocol (TT: 41.32%, 150/363; IT: 26.28%, 36/137; $P=0.0006$).

The TT group of respondents were more likely to ‘strongly agree’ with the following statements: “I believe that wormers are bad for my horse and want to minimise their use as far as possible” (TT: 21.32%, 71/333; IT: 5.6%, 7/125; $P<0.0001$); “I am aware of the emergence of wormer resistance in horses and this concerns me” (TT: 59.46%, 198/333; IT: 34.4%, 43/125; $P<0.0001$); and, “Knowing how many eggs are being shed by horses helps me to manage grazing so that horses do not encounter heavily contaminated pastures” (TT: 25.31%, 81/320; IT: 7.38%, 9/122; $P<0.0001$). Those respondents who followed TT protocols were significantly more likely to ‘strongly disagree’ with the statements “FEC are too expensive and provide no advantage over administering wormer regardless of results” (TT: 52.5%, 168/320; IT: 4.1%, 5/122; $P<0.0001$) and “Not enough advice on what to do arrives with FWEC for them to be useful to me” (TT: 36.56%, 117/320; IT: 6.56%, 8/122; $P<0.0001$).

Those respondents who followed an IT protocol were more likely to ‘strongly agree’ with the statement “If FEC were quicker and cheaper I would use them more” (TT: 9.69%, 31/320; IT: 25.41%, 31/122; $P<0.0001$). On the other hand, the IT group were more likely to ‘disagree’ with the statement

"Worms are something our horses have to live with and are not always bad for them" (TT: 29.43%, 98/333; IT: 48%, 60/125; P<0.0001).

In terms of reported anthelmintic treatment practices, the respondents in the TT group were more likely to select 'yes' when asked if they treated for tapeworm (TT: 81.9%, 276/337; IT: 65%, 82/126; P<0.0001) or encysted cyathostomin larvae (TT: 66.77%, 225/337; IT: 48.41%, 61/126; P<0.0001). Finally, the IT group of respondents were more likely to seek advice from an internet retailer compared to TT participants (TT: 2.97%, 10/337; IT: 9.52%, 12/126; P<0.0001).

4. Discussion

This study examined helminth control approaches of horse owners in the UK. Participation was similar to a recent survey in the UK (Easton et al., 2016) and relatively higher than previous UK studies that focused on particular regions or sectors, i.e. 193 responses in a study focused on horse establishments in Scotland and 61 responses in a study focused on UK thoroughbred establishments (Relf et al., 2012; Stratford et al., 2014). An important finding was that 60.9% of respondents stated that they followed a TT regimen based on FEC testing, the majority of whom switched from IT protocols in the preceding 1-5 years before this survey. The percentage of owners following a TT strategy based on FEC test results reported here is the highest reported to date. For example, a study conducted in Scotland in 2010 (Stratford et al., 2014), indicated that 40% of respondents followed TT regimens. The last UK-wide survey, conducted in 2009-2010, targeted Thoroughbred breeding farms and in that case, 100% of respondents followed an IT regimen (Relf et al., 2012). Studies based outside of the UK also demonstrated a lower uptake of TT protocols; for example, 25% in France (Salle and Cabaret, 2015); 20% in New Zealand (Bolwell et al., 2015); 30% in the USA (Robert et al., 2015); 50.6% in Denmark (Nielsen et al., 2014b); 0% in Germany (Fritzen et al., 2010); 1% in Sweden (Lind et al., 2007) and 16% in the Republic of Ireland (O'Meara and Mulcahy, 2002).

The results presented here should be interpreted in consideration of inevitable bias. The sample size, although higher than similar UK studies (Relf et al., 2012; Stratford et al., 2014), is approximately 0.15% of the estimated 446,000 horse-owning premises quoted in The National Equestrian Survey 2015 (BETA, 2015). The distribution/promotion of the current survey was online, which might lead to non-response bias by only reaching those individuals with access to the internet. Nevertheless, a recent study has demonstrated that online questionnaires could potentially replace hard-copy questionnaires without compromising response rates (Hohwu et al., 2013). This questionnaire was partly distributed via equine veterinarian practices to their clients, which could also have skewed the results towards approaches that those practices promote. It is also possible that horse owners who participated here were more in favour of using FEC tests and the currently-recommended approaches. Finally, there could also be a social desirability bias. This type of response bias is the increased likelihood that survey participants select answers in such a manner that will be viewed favourably by others. This type of bias was recently described in a horse owner survey as a factor influencing the use of FEC tests before treatment (Rose Vineer et al., 2017).

Here, respondents had a good general knowledge of parasites/parasitic disease. When asked to identify the most important parasites to target, many responses matched the reports in scientific articles; namely cyathostomins as the most important parasite to target, followed by tapeworm and large strongyles (Kaplan and Nielsen, 2010). Respondents using TT protocols were more satisfied with their level of parasitology knowledge compared to IT-participants. This is similar to a previous UK survey study that also showed that horse owners who were less satisfied with their level of knowledge were 57% less likely to follow TT strategies (Allison et al., 2011). Nevertheless, in the current study, just under a quarter of respondents were still not satisfied with their knowledge levels, highlighting a requirement for improving knowledge transfer to horse owners in the UK.

The most commonly used anthelmintic class reported in previous studies in the UK and elsewhere was the macrocyclic lactones (Fritzen et al., 2010; Hinney et al., 2011; Relf et al., 2012; Stratford et al., 2014; Robert et al., 2015; Salle and Cabaret, 2015) and this was the case for the current study. Note that treatment frequency was not recorded here because it was difficult to assimilate information in the TT group as, at certain times, treatment was linked to egg shedding levels in individuals. The high reliance on macrocyclic lactones needs to be addressed, especially in IT programmes, because of the strong selection pressure for resistance caused by regular treatments using the same type of compound (Matthews, 2008; Tzelos and Matthews, 2016). A total of 74 (out of 463) respondents stated that; "I do not know what these chemical terms are". This is of concern and indicates sub-standard information transfer at the point of sale or in the advice given before purchase.

Anthelmintic resistance was the topic that most respondents were concerned about, with those using TT protocols significantly more concerned about this issue compared to the IT group as indicated by the Chi-square analysis here. Nevertheless, approximately 75% of the overall study population were not aware of the status of anthelmintic resistance in worm populations at their premises. This particular discrepancy has also been reported in the past in a questionnaire study examining the interaction of horse owners with anthelmintic prescribers (Easton et al., 2016). Potential reasons associated with the lack of efficacy testing include the perception of additional labour in collecting the samples and the additional economic cost. Another potential reason might be the lack of promotion or emphasis of efficacy testing by prescribers to horse owners. Current recommendations are that a FECRT be performed each year to avoid using ineffective anthelmintics (Tzelos and Matthews, 2016). Going forward, considering the levels of anthelmintic resistance reported in cyathostomins and in *P. equorum* (Raza et al., 2019), improved knowledge transfer from prescribers to horse owners needs to highlight the benefit of efficacy testing.

Although the majority of respondents sought advice on anthelmintic selection from a veterinarian or SQP, only a small proportion bought anthelmintics from these sources, with the main route of purchase being internet retailers. A recent analysis of UK horse owner anthelmintic purchasing behaviours similarly demonstrated that most respondents received advice from veterinarians before purchasing dewormers online (Easton et al., 2016). In the current study, it was more likely that respondents would follow an IT protocol when advice was sought from an internet retailer. Getting information from an internet retailer is not ideal; one study showed that horse owners who purchased anthelmintics online most often stated they received little/no specific advice at the point of purchase (Easton et al., 2016). Face-to-face interactions with veterinarians or other qualified prescribers (in the UK, SQPs or veterinary pharmacists) should be encouraged as it has been shown that horse owners who purchased anthelmintics from veterinarians (and other prescribers, SQPs or veterinary pharmacists) were more likely to be recommended FEC test analysis in their interaction than online retailers (Easton et al., 2016).

It was more likely for IT-participants to treat *all* new acquisitions with anthelmintics than those following a TT protocol. Approximately 12% of TT-participants performed FEC analysis on new arrivals and applied a treatment based on the test results. The latter approach would not inform on the presence of immature helminth stages and standard FEC analysis is unlikely to provide information on the presence of *Anoplocephala perfoliata* infection. Thus, it is recommended that new acquisitions be treated with a product containing moxidectin to target strongyle larvae and adult stages and that these horses be kept off pasture for at least 3 days after treatment (Tzelos and Matthews, 2016). Testing for *A. perfoliata* infection using an ELISA-based test (in the UK) or treatment with praziquantel is also recommended (Tzelos and Matthews, 2016). Here, a product containing moxidectin was used by only 32.3% of respondents when treating new arrivals. Best practice quarantine recommendations need to be disseminated more widely.

Foal treatment was another aspect that a knowledge gap was identified. Current suggestions for foal treatment include specific treatments at specific time due to the relatively long prepatent period of ascarid infections, which should be the main focus for foals (Tzelos and Matthews, 2016). Most participants that replied to this question (37.1%; 26/70) stated that they used the same anthelmintics with adult horses, but with different dosing regimen. It is worth mentioning here that a total of 39/70 respondents that replied to the previous question stated that they had nil foals. This discrepancy could be because they might not had foals at their premises at the time the survey took place, but they did in the past and felt like they should answer the question. Generally, more emphasis should be given in advice on helminth control practices in foals in the future.

Dung removal from pasture plays a crucial role in reducing infection pressure in the environment (Herd, 1986). Here, 74.4% respondents stated that they removed dung, similar to levels in a recent UK survey where ~80% of respondents stated that they did this (Easton et al., 2016). These levels of uptake are the highest reported to date and are higher than reported in other countries (O'Meara and Mulcahy, 2002; Lind et al., 2007; Fritzen et al., 2010; Bolwell et al., 2015) and offer hope that some messages on sustainable helminth control are reaching the target audience in the UK. Potential reasons associated with the unwillingness of horse owners/managers to engage with this activity include land gradient, increased horse numbers, labour associated, limited staff resources and/or lack of knowledge.

5. Conclusion

Overall and despite the aforementioned limitations, the results of this study highlight; 1) a recent shift from IT to TT strategies on many yards in the UK, 2) some confusion in the interpretation of current quarantine treatment guidelines, 3) a lack of anthelmintic efficacy testing overall and 4) high proportions of the horse owners purchasing anthelmintics online. The areas in which knowledge gaps were identified should be considered to enhance knowledge dissemination in the future. Improving knowledge in horse owners, especially in those who do not use a face-to-face interaction for advice on helminth control, could be facilitated by developing accurate knowledge-transfer tools such as free guidelines or decision support tools. Alternatively, these issues could be addressed by altering prescribing legislation to promote better quality face-to-face interactions when anthelmintics are sold and minimise the amount of anthelmintics purchased online.

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