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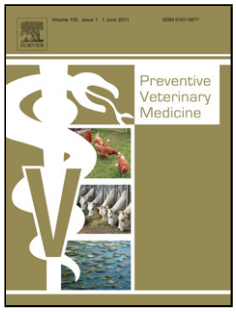

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Investigating interactions between UK horse owners and prescribers of anthelmintics

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ABSTRACT

Helminths are common pathogens of equids and anthelmintic resistance is a major issue in cyathostomin species and *Parascaris equorum*. At the heart of mitigating the impact of increasing anthelmintic resistance levels, is the responsible dissemination and use of these medicines following best practice principles. There is a paucity of information on interactions between horse owners and anthelmintic prescribers and how this shapes control. Here, a study was undertaken to determine opinions and experiences of horse owners as they relate to anthelmintics purchase and implementation of best practice control. An online survey was distributed via email and social media to explore owners' experiences of purchasing anthelmintics from United Kingdom prescribers, these being veterinarians, suitably qualified persons (SQPs) and pharmacists. Owner responses (n=494) were analyzed statistically to compare answers of respondents grouped according to: (i) from whom they bought anthelmintics (Veterinarians n=60; SQPs n=256; Pharmacists n=42; More than one channel n=136), and (ii) by which route (Face-to-face n=234; Telephone n=31; Online n=226) they purchased. Owners who purchased from veterinarians predominantly did so face-to-face (81.3%), whilst those that bought from SQPs purchased via face-to-face (48.8%) and online (46.0%) interactions. Those who purchased from pharmacists predominantly bought anthelmintics online (76.2%). Participants who bought from veterinarians were more likely to view certain factors (i.e. time to talk to the supplier, supplier knowledge) as more important than those who purchased from other prescribers. Those who purchased from veterinarians were more likely to be recommended faecal egg count (FEC) test analysis; however, there was high uptake of FEC testing across all groups. There was a low uptake of anthelmintic efficacy testing; regardless of the prescriber type from whom anthelmintics were purchased. Those who purchased from veterinarians were more likely to agree that anthelmintics should be sold as veterinary prescription-only medicines. Those who purchased online (regardless of

which type of prescriber they bought from) were less likely to consider prescriber advice or knowledge when deciding which product to buy and indicated that sellers were less likely to raise use of anthelmintics for targeting parasites. Across all groups, many owners stated that they were aware of or used non-chemical control measures such as dung removal and diagnostic FEC testing to target treatments. In summary, there were some differences in the type of advice provided at the point of purchase and this was dependent upon whom anthelmintics were purchased from and by which route they were bought.

1. Introduction

Gastrointestinal nematodes of equids are an important cause of disease worldwide (Nielsen et al., 2010; Reinemeyer, 2012; Matthews, 2014a). Traditionally, control of these parasites has been achieved using all-group interval treatment programmes (Smith 1976; Nielsen, 2012). While these programmes have been proposed to have led to a reduction in parasite-associated disease in equids, they have contributed to the widespread prevalence of anthelmintic resistance in some nematode species (Kaplan, 2002; Matthews, 2014b; Peregrine et al. 2014). Resistance to benzimidazoles and tetrahydropyrimidines is widespread in the highly prevalent cyathostomin group of nematodes, with emerging resistance to macrocyclic lactones also reported in these parasites (Kaplan, 2002; von Samson-Himmelstjerna, 2012; Matthews, 2014b). There have also been many reports of resistance to macrocyclic lactones in the common parasite of foals, *Parascaris equorum* (Reinemeyer, 2012). From the publicly available information, it would appear that no new equine anthelmintic compounds are near market in the short to mid term, so control programmes must now balance the maintenance of potency of any currently-effective anthelmintics with the necessity to control disease associated with pathogenic burdens. In the last 10-20 years, helminth control programmes that involve the use of diagnostics such as faecal egg count (FEC) analysis and/or the application of strategic anthelmintic treatments at specific times of year have been recommended (Herd, 1993; Proudman and Matthews, 2000; Uhlinger, 2007; Lester and Matthews, 2014; Nielsen et al. 2014). Nematode egg shedding is highly overdispersed in horses (Gomez et al., 1991; Döpfer et al., 2004; Matthee and McGeoch, 2004; Lloyd, 2009; Relf et al., 2013) and so FEC-directed treatment programmes can substantially reduce the frequency of anthelmintic administration within populations. It is essential that this type of targeted anthelmintic therapy is integrated with good management practices such as dung removal, weight calculation before dosing, rotational grazing and effective quarantine

treatments. Furthermore, efficacy testing should be implemented regularly to assess nematode population sensitivity to specific anthelmintic compounds (Matthews 2014b; Nielsen et al. 2014). In consideration of all of this, it is vital that information regarding the appropriate, and responsible use of, anthelmintics is disseminated to horse owners at the point of purchase. Whilst some EU countries prohibit anthelmintic use on a metaphylactic basis and require a parasitological diagnosis by a veterinarian prior to dispensing (Nielsen et al. 2006; Nielsen, 2009), this is not the case in other countries. In the UK, the prescribing situation is unique. Here, legislation classifies anthelmintic medicines under different categories; those anthelmintics (POM-VPS) that can be sold on prescription by veterinarians, pharmacists or Suitably Qualified Persons (SQPs) or those that can be sold on prescription by veterinarians only or by a pharmacist under veterinary prescription (POM-V) (VMR, 2011). Currently, all United Kingdom (UK) equine anthelmintics are classified as POM-VPS medicines and, as such, there is no requirement to conduct a clinical assessment prior to prescribing these medicines. Recently, debate has surrounded the complexity of this prescribing system, particularly regarding which type of prescribing channel, if any, is best placed to supply these medicines (Anon, 2013a, Anon, 2013b). Accordingly, the aim here was to investigate how UK horse owners interact with the different types of anthelmintic prescribers and to explore their attitudes to the responsible use of these commonly used medicines, for which drug resistance is a major issue.

2. Materials and methods

2.1. Ethical statement

Ethical approval for this survey was granted by the UK Department for Environment Food & Rural Affairs Survey Control Unit. Regarding respondent confidentiality, all information

obtained was anonymised and was stored on a secure server at Moredun Research Institute. The data were backed up daily at an external site.

2.2. Study population and study design

For selection of horse owners, 384 equine veterinary practice email addresses were obtained from the British Equine Veterinary Association website (beva.org.uk). An email detailing the background to the study and an online link to the survey questionnaire was distributed to these practices inviting them to promote the survey to their clients via websites, social media and/or newsletters. At the same time, an email was also distributed to 393 horse owners/managers. This group comprised a population from a concurrent questionnaire study on equine helminth control practices and who had intimated they would like to be involved in future surveys of the authors (Tzelos et al., unpublished). These contacts had been accessed through information lists on the British Horse Society website (bhs.org.uk/professionals/become-bhs-approved/approved-livery-yards), as well as through information available on equine sites on social media. To further increase participation, the survey link was shared on the pages of a number of equine-orientated groups on Twitter (twitter.com) and Facebook (facebook.com). After initial introduction of the survey link, reminders were posted approximately every other week. The survey was open for 10 weeks (July-September 2015).

The survey (available as Supplementary Material, Appendix 1) comprised demographic questions (n=10). These were followed by specific question sections; the first relating to 'purchasing anthelmintics' (n=13), followed by 'anthelmintic resistance (AR) and best practice guidelines' (n=5) and ending with 'views on responsibility' (n=3). Informed consent was sought from all participants. The survey questions were presented in a variety of formats:

matrices, multiple choice, open-ended text boxes and rating scales. Some questions were accompanied by an open-ended response box for voluntary comments (n=15). The questions were disseminated using online cloud based software (SurveyMonkey©, surveymonkey.co.uk). On completion of the questionnaire, the respondents were directed to further information on equine helminth control (moredun.org.uk/research/research-@-moredun/parasitic-worms/parasite-control-in-horses). The test was piloted on a small number of horse owners before distribution.

2.3. Data analysis

Responses were exported to Microsoft Excel (Microsoft Excel for Windows, 2010). Manipulation included collapsing of answer categories for a number of ranking questions (i.e. five-point Likert scales which were reduced to three points), as well as re-categorisation of answers provided as open-ended or 'other' options (i.e. specific 'other' responses provided for location re-categorised into appropriate regional group), to reduce the variables and aid analysis. Basic descriptive statistics were carried out on all questions prior to statistical analysis. The survey was analysed question-by-question and respondents who had provided an answer to a single question beyond basic demographic questions were included in basic descriptive statistics, regardless of whether they completed the survey. For comparative analyses by purchase channel, only participants who had proceeded beyond the question necessary for breakdown into channel (veterinarians, SQPs, pharmacists, > 1 prescribing channel) were included. Subsequently, the sample was grouped by purchase route (face-to-face, telephone, online) and a second analysis conducted. Analyses were carried out using chi square tests. Due to testing of multiple comparisons (n=14), following correction via Šidák's formula (Šidák, 1967), values of $p \leq 0.003$ were considered significant.

3. Results

3.1. Study sample and demographics

A total of 733 respondents clicked on the link, of which 687 met the criteria for inclusion in basic descriptive analysis; 38 were excluded as they did not provide information beyond consent (Table 1). Eight more were excluded due to not being UK-based. The study sample was predominantly female (96.5%), with many aged 30 to 59 (72.5%) and the largest proportion located in south England (57.7%). These demographics reflect those reported in The National Equestrian Survey 2015 (BETA, 2017), with the exception of age range, in which most riders were in the range 16 to 24; however, these are representative of riders not owners. Most participants owned 1-10 equids, which were aged 4 or more years-old (87.8%), and which were most likely to be kept on livery yards (43.4%). Most participants (>90%) indicated that they purchased and administered anthelmintics (Supplementary materials, Appendix 2: Table 1). There was a high level of owner familiarity with the terminology cited for all helminth species names stated in the survey question (Fig. 1), with the least recognised names being liver fluke, ascarids and pinworms. Regarding consideration of which helminths were perceived as an 'issue' in the respondents' equids, the highest levels of concern were in relation to small redworms (cyathostomins, 35.4%) and tapeworm (*Anoplocephala perfoliata*, 28.8%).

3.2. Anthelmintic purchasing behaviours of UK horse owners

A total of 494 respondents provided enough information to be grouped into the channel from which they purchased anthelmintics, as well as their primary route of purchase (Table

2). Of these, 60 purchased anthelmintics from veterinarians, 256 from SQPs, and 42 from pharmacists, with 136 respondents stating that they purchased anthelmintics from >1 prescribing channel. Most interactions were face-to-face (n=234) or online (n=226), with 31 respondents stating that they purchased anthelmintics via the telephone. There was a significant difference (p=<0.001) dependent on from whom owners bought anthelmintics (veterinarian; SQP; pharmacist; >1 prescriber type) and the route through which they purchased these medicines. Those who purchased from veterinarians predominantly bought anthelmintics in a face-to-face interaction (face-to-face 47/58 [81.0%], telephone 9/58 [15.5%], online 2/58 [3.5%]). Those who bought anthelmintics from SQPs purchased through two main routes: face-to-face 123/255 (48.2%) and online 119/255 (46.7%), with a lower proportion (13/255, 5.1%) via telephone transactions. Those who purchased from pharmacists predominantly bought anthelmintics via an online transaction (face-to-face 8/42 [19.1%], telephone 2/42 [4.8%], online 32/42 [76.2%]). The relatively large proportion of owners (27.5%) who stated that they obtained anthelmintics through >1 channel, purchased these medicines through different routes, most commonly online (face-to-face 56/136 [41.2%], telephone 7/136 [5.2%], online 73/136 [53.7%]). Regarding when anthelmintics were purchased (Appendix 2, Fig. 1), anthelmintics were bought most frequently in spring (range 64.3-80.9%) and autumn (range 69.0-81.6%) and less frequently in winter (range 49.2-59.5%) and summer (range 27.0-39.0%). These trends were similar regardless of the prescriber type from whom anthelmintics were bought, or the route by which these medicines were purchased.

3.3. Prescriber/horse owner interactions and sources of knowledge

Participants who purchased from veterinarians were likely to view certain factors as important more than those purchasing from other prescribers (Table 3). These factors included; time to talk with the supplier and supplier knowledge of the animals being prescribed for, supplier knowledge of parasites, supplier knowledge of anthelmintics, supplier knowledge of drug resistance and supplier knowledge of diagnostics. Fig. 2 shows that all groups were generally happy with the advice that they received, with no significant difference among the groups partitioned according to which channel they purchased anthelmintics from. With the exception of respondents who purchased from veterinarians, there were individuals in each group who stated that they 'received little or no advice' on anthelmintic use. When asked about the level of advice required when purchasing anthelmintics (Table 4), most respondents in each group (>60%) stated that they usually know which anthelmintic to buy, but sometimes require assurance/further guidance. Between 10.5% (veterinarian purchase group) and 27.5% (pharmacist purchase group) stated that they do not require specific advice when purchasing anthelmintics, but there was no significant difference amongst the groups.

In relation to awareness or use of initiatives for promoting responsible anthelmintic use (Appendix 2: Table 2), those who purchased from veterinarians were significantly more likely to use veterinarian websites as sources of information on helminth control. When asked about how participants felt about the relative importance of different sources of information when deciding on anthelmintic selection (Appendix 2, Table 3), those who purchased from veterinarians were significantly more likely to cite veterinarians as 'important sources' more than the other groups. Likewise, those who purchased anthelmintics from pharmacists cited these prescribers as important sources significantly more than those who bought anthelmintics from other prescriber types. For the other parameters, there were no significant differences among the groups. When specifically asked 'who most influences' anthelmintic selection, most owners who purchased from veterinarians (>90%) stated that they considered

those prescribers to most influence their selection (Fig. 3). Those that purchased from SQPs stated that they considered SQP prescribers to most influence choice, but approximately 30% of these respondents cited that it is veterinarians that most influence anthelmintic selection. Those who purchased from pharmacists stated that they were most influenced by veterinarians and SQPs rather than by pharmacists. Participants who purchased from >1 prescriber type stated that they were influenced by veterinarians most, then by SQPs.

3.4. Awareness and implementation of best practice in the use of equine anthelmintics

Regarding how often participants stated that they considered; a) weighing horses or using a girth tape to estimate weight prior to anthelmintic administration, b) ensuring that the full dose was swallowed and c) undertaking of quarantine treatments (Appendix 2: Table 4), there were no significant differences found between the prescriber type groups. In all groups, >70% participants stated that they weighed horses and/or used a girth tape prior to anthelmintic administration, with >90% participants in each group stating that they ensured that the full dose was swallowed (Appendix 2, Table 4). Regarding the application of quarantine treatments, there was no significant difference between groups; levels of agreement varied from 80% of those that purchased from veterinarians stating that they applied quarantine treatments, with the lowest levels of agreement (55.6%) in those that purchased from pharmacists. When asked how often participants considered specific factors (i.e. parasite/developmental stage, number of animals, diagnostic tests, own/others' experience, product persistence/withdrawal period, brand, applicator, prescriber advice) when deciding which product to use (Appendix 2: Table 5), there were no significant differences amongst the groups that purchased from the different channels.

When asked about whether specific recommendations for responsible use were raised by their anthelmintic seller, participants who purchased from veterinarians were significantly more likely to state that their sellers mentioned FEC testing (Table 5). There were no significant differences among the groups in the other parameters listed, although anthelmintic targeting, resistance, efficacy testing, dung removal, rotational grazing and quarantine treatments were stated to be raised more in interactions with veterinarians than with other prescriber types.

Regarding the frequency with which sellers recommended FEC testing (Appendix 1, Question 26), as opposed to whether or not they raised the topic (Question 22, Table 3), participants who purchased from veterinarians were significantly more likely to have this recommended, with the least likely being those who purchased from pharmacists (veterinarians 82.5%; SQPs 47.1%; pharmacists 33.3%; >1 channel 58.3%, p=<0.001). No significant differences were found between groups in relation to whether participants had conducted anthelmintic sensitivity testing (Question 27, 'Have you ever conducted anthelmintic sensitivity testing on your premises, such as a faecal egg count reduction test?': veterinarians 43.9%; SQPs 47.5%; pharmacists 37.5%; >1 channels 48.9%). When asked about integrating anthelmintic treatments with various management measures, many (>75% in each group) participants stated that they already used dung removal and >60% in each group stated that they already used FEC testing for targeting anthelmintic treatments (Appendix 2: Table 6). Compared with FEC testing, lower numbers of participants stated that they already used the blood- or saliva-based tapeworm diagnostic tests, with no significant difference between the groups. There was a high level of agreement on whether respondents would make use of a serum-based ELISA designed for the detection of cyathostomin infection in future, with >70% of respondents stating that they would utilise such a diagnostic test. There was no significant difference among groups when asked about concern for

anthelmintic resistance in participants' horses, with relatively high levels stating concern in all groups (Question 28, 'Are you concerned about anthelmintic resistance?': veterinarians 68.4%; SQPs 58.8%; pharmacists 45.0%; multiple channels 57.4%).

3.5. Owners' views on equine anthelmintics distribution

Participants who predominantly purchased from veterinarians were significantly more likely to agree that new classes of equine anthelmintics should be available by veterinary prescription only (Table 6). With regard to categorisation of current anthelmintics, participants purchasing through veterinarians were also significantly more likely to agree that all (current and new) anthelmintics should be available by veterinary prescription only. Regarding whom participants felt were important in ensuring anthelmintics are used responsibly, there were no significant differences between groups, with generally high agreement that responsibility should be shared among owners and all prescribers; >70% of participants in all groups stated that they viewed all parties cited in the survey as important (data not shown).

3.6. Analysis based on the route by which owners purchased anthelmintics

To explore if the route (face-to-face, telephone, online) through which participants purchased anthelmintics was associated with particular experiences or behaviours, we analysed responses according to this variable. Those purchasing anthelmintics online were significantly more likely to view cost as an important factor ('Important': face-to-face 56.2%; telephone 60.7%; online 80.6%, p=<0.001) and were also more likely to view several factors as not important, including time to talk with the supplier ('Not important': face-to-face

16.7%; telephone 14.3%; online 25.3%, p=<0.001), as well as suppliers' knowledge of: the owner's equids ('Not important': face-to-face 9.4%; telephone 3.6%; online 18.8%, p=<0.001), parasites ('Not important': face-to-face 9.2%; telephone 3.5%; online 14.8%, p=<0.001), anthelmintics ('Not important': face-to-face 7.0%; telephone 3.5%; online 14.1%, p=<0.001), anthelmintic resistance ('Not important': face-to-face 7.0%; telephone 3.5%; online 12.7%, p=<0.001), and diagnostics ('Not important': face-to-face 8.8%; telephone 3.6%; online 13.7%, p=<0.001). For factors considered when deciding which product to use (Question 19), there was a significant difference in the frequency with which participants would consider prescriber advice, with those who purchased online less likely to consider this (face-to-face 81.1%; telephone 86.2%; online 60.8%, p=<0.001). This was confirmed by responses to Question 29 (Table 4), where those who purchased online were significantly less likely to state that they relied on seller knowledge (p<0.001). With regard to how important participants perceived sources of information to be in relation to their decision on which anthelmintic to choose (Question 20), the only significant difference identified was those who purchased online were more likely to place importance on online information sources (Very-Quite important; face-to-face 43.8%; telephone 35.7%; online 61.7%, p=<0.001). In relation to awareness of initiatives for promoting responsible use (Appendix 2, Table 2), there was a significant difference regarding veterinary surgeon websites, with those purchasing online stating more frequently that they were aware of, but did not use, this source (face-to-face 30.0%; telephone 18.5%; online 43.4%, p=<0.001). When asked, 'When purchasing anthelmintics, how often are the following points raised by the seller?' (Question 22), the only significant difference identified was that those who purchased online stated that their seller raised the topic of 'using an appropriate anthelmintic for the parasites being targeted' significantly less often than those buying via face-to-face and telephone routes (face-to-face 80.9%; telephone 83.3%; online 62.9%, p<0.001). There were no significant differences

between purchase route groups on views regarding the categorisation of new classes of anthelmintic; however when asked about all anthelmintics (including current products), participants who purchased online were significantly more likely to disagree that all anthelmintics should be available by veterinary prescription only (Table 6).

4. Discussion

Here, we investigated how UK horse owners interact with anthelmintic prescribers to explore attitudes to responsible use. Our recent studies investigated these prescribers' basic knowledge of helminths, legislation and best practice (Easton et al., 2016) and also how prescribers transferred information to clients and customers at the point of dispensing (Easton et al., in press). Here, we expanded our previous observations by surveying equine industry end-users' experience of these prescribers as they relate to practices before, and at the point of, dispensing anthelmintics. We highlight important differences depending on who anthelmintics are bought from and the route through which they are purchased. In our previous prescriber study (Easton et al., in press), the results showed similarly high proportions of veterinarians and SQPs engaging face-to-face with horse owners, with a higher proportion of the latter utilising online transactions; thus, our two studies are in agreement. Furthermore, in our earlier studies, the response rate for pharmacists was nil or negligible, so we excluded this prescriber group from the analyses. In the current study, there were sufficient respondents who purchased anthelmintics from pharmacists to permit analysis of this group, thus providing new insight into the practices of this channel of UK prescribers.

Although the anthelmintic prescribing situation in the UK is unique, the outcome of this study could affect perceptions regarding anthelmintics distribution among stakeholders in other regions. For example, in those countries where there is no requirement for veterinary

prescription to purchase anthelmintics, the data generated here could provide insights into how horse owners might respond to a change in the legal regulatory categorisation of anthelmintics to that of tighter distribution. Alternatively, in regions where equine anthelmintics are under stricter regulation and only available from veterinarians following a parasitological diagnosis (for example, as in Denmark), the outcomes could provide insight into what the impact could be of opening up prescribing authority to a wider range (i.e. non-veterinary) of animal health advisors. For this reason, the observations made here might help inform risk/benefit-led decisions relating to a change in legal prescribing category of equine anthelmintics.

The results here need to be viewed in consideration of inevitable biases. While it is not possible to quote exact numbers of horse owners in the UK, The National Equestrian Survey 2015 (BETA, 2015) estimated 446,000 horse-owning households with around 796,000 horses estimated in 2015, although the quoted figures range from 390,000 to 1,000,000 equids (http://www.worldhorsewelfare.org/Removing-the-Blinkers). Based on these numbers, the proportion of the population represented here is very low; a recognised disadvantage of web-based surveys (Shih and Fan, 2008). Potential bias-related issues include responder bias due to only reaching individuals with access to the internet (Fricker et al., 2005) or that the respondents might be inherently more interested in equine helminth control and hence possibly more receptive to more up-to-date recommendations. This latter fact could, to some extent, explain the high level of adoption rate of the non-chemical control measures and targeted FEC-based selective therapy. Furthermore, results for the veterinarian purchase channel may be vulnerable to bias due to the fact that the survey was, in part, distributed via practices to their clients. Nevertheless, surveying views of these end-users is a valuable endeavour through which to counter certain inevitable biases of our previous studies; for example, self-serving bias where prescribers may have been driven to maintain self-esteem

(Shepperd, Malone and Sweeny, 2008) to maintain a better profile for their relationship with clients or customers. In the same way, the prescribers may have been affected by a social desirability bias, where they may have been driven to present themselves in a more acceptable way (King and Bruner, 2000) and so encourage end-users (here, horses owners) to select their prescribing channel for purchase, or to try influence any future decisions by regulatory authorities on the legal distribution category of equine anthelmintics. Nevertheless, the similar findings obtained when comparing the end-user owner responses here to the earlier responses of the prescribers goes some way to supporting the reliability of the results obtained from both studies.

Here, owners who purchased from veterinarians appeared to value the role of the prescriber more than those who bought from other prescriber types. Owners in this group were significantly more likely to view the following factors as important in their interactions when buying anthelmintics: time to talk with the prescriber, as well as the supplier's knowledge of their animals, the target parasites, anthelmintics, drug resistance and parasite diagnostics. Those who purchased from veterinarians were also more likely to be recommended FEC test analysis. These results may reflect the mode of contact with veterinarian prescribers as most interactions were face-to-face. This group were also more likely to agree that all anthelmintics should be available as POM-V medicines, presumably because a change to this legal category would not result in an alteration in purchasing behaviour or financial cost to themselves. This group were also more likely to place the highest level of responsibility for best practice control on their seller. Anthelmintics are likely to be more costly when bought from veterinarians (Kaplan, 2013) and, due to assumptions that quality and price might be correlated (Kardes et al., 2014), this may influence the perceptions held by those horse owners that use veterinarian prescribers. In addition, these participants' feelings could be influenced by a favourable view of veterinarian academic

achievements. Overall, the responses indicate that this group of horse owners spend more time considering anthelmintic choice via a direct interaction with their veterinarian and, in so doing, view cost as less important than quality of advice on their helminth control strategy. The number of respondents in this group was relatively low and, as such, cannot be considered representative of the UK anthelmintics-buying population as a whole. Those purchasing through other types of prescriber were less likely to agree with a change to a POM-V categorisation (to be expected given that they currently purchase from non-veterinarians). For those that bought from SQPs, there was a partitioning in buying route, with 46.0% buying online and 48.8% face-to-face. This likely reflects the diversity of outlets where SQPs may work, with some employed in retail premises and others in online merchants (AMTRA, 2014). As similar numbers of participants purchased via SQP face-to-face and SQP online transactions, there may have been diversity in responses within this group. To examine if this affected the results, we examined responses by dividing the SQP-buying group into 'face-to-face' and 'online' buyers (data not shown). The only differences identified were that those who bought online stated that they valued factors relating to cost significantly more often than those who purchased face-to-face, while the latter group indicated that they valued supplier knowledge and prescriber advice significantly more. Regardless of purchase route, the SQP group stated that they attributed responsible use of anthelmintics highly to both SQPs and veterinarians. This may be due to the fact that individuals may receive, or read, advice from veterinary sources before purchasing from another prescriber source. Those owners who purchased anthelmintics through the pharmacist channel were significantly more likely to view supplier knowledge as less important, consider prescriber advice less and were more likely to disagree that anthelmintics should be available as POM-V medicines. Those who purchased anthelmintics from >1 channel cited that anthelmintic choice was most influenced by veterinarians; however, in terms of whom they

attributed responsibility for ensuring appropriate use, they shared this equally between veterinarians, SQPs and yard owners.

While most participants were aware of, and concerned about, anthelmintic resistance, evidence from environmental psychology studies suggests that such awareness does not necessarily lead to pro-environmental behaviour, possibly due to internal (i.e. motivation) and external (i.e. economic) factors (Kollmuss and Agyeman, 2002). This could explain the observations here, whereby individuals appeared to be concerned about resistance but, even though it is argued that stricter distribution regulations could help mitigate this, many did not want equine anthelmintic categorisation legislation to change as this could conflict with cost and convenience. For example, provided through voluntary comments sections in the survey, when reflecting on a change to POM-V status, respondents wrote, "*Expensive, so I think it will put off people getting them*", and "*It then becomes a closed market and you can then bet that the vets will insist on only them doing FEC's before they will prescribe anthelmintics*". This suggests that some owners believe that there will be undesirable sequelae as a result of a change to a POM-V categorisation, which could potentially result in the application of inadequate anthelmintic treatments. Our results also suggested that a higher proportion of participants agreed that any new classes of anthelmintics should be available as POM-V medicines. This may reflect that there are no new equine anthelmintic classes on the horizon, meaning that views given by the respondents may be more speculative than would be the case for those purchasing livestock anthelmintics, of which two recently-licensed anthelmintic products are classified as POM-V in the UK. It might also reflect that horse owners could be more concerned about possible adverse sequelae when administering newly-licensed (i.e. perceived as not 'tried and tested') pharmaceutical compounds, and would thus prefer these to be under tighter distribution through veterinarians.

Despite high levels of concern for resistance stated by participants, low proportions indicated that they had conducted anthelmintic sensitivity testing. This apparent paradox between horse owner concern regarding anthelmintic resistance, yet an apparent lack of uptake of sensitivity testing may be associated with a perception of the additional effort involved in sampling, as well as the financial cost of testing. It could also be that prescribers or other types of FEC service providers, until now, have not placed much emphasis the importance of efficacy testing. A search of the internet by the authors indicates that some FEC service providers now advocate the value of efficacy testing and provide financial incentives to use these; so this may help increase uptake of sensitivity testing in future. It is recommended that, as part of post-graduate or post-certificate training initiatives for prescribers, these groups be educated in the value and methods of efficacy testing as, given the increasing issue of resistance in cyathostomins and *P. equorum*, all prescribing groups should encourage efficacy testing as part of an integrated control programme.

Regarding owner awareness and/or utilisation of initiatives for promoting responsible use of anthelmintics, highest levels of awareness/use were cited for veterinary surgeon websites, regardless of who the participants bought anthelmintics from. There is currently a lack of cohesive advice for helminth control for horse owners in the UK, with no equivalent of the SCOPS (SCOPS.org.uk/) or COWS (cattleparasites.org.uk) initiatives that are available to support the sheep and cattle industries, respectively. Nor is there a resource that is equivalent to the guidelines that are available for the control of equine parasites in the US, which have been generated by the American Association of Equine Practitioners (aaep.org/info/parasite-control-guidelines). In the UK, there are several online sources available from veterinary organisations, charities and animal health companies and it would be beneficial for such organisations to work together to develop industry-wide guidelines where horse owners could access accurate information about resistance, diagnostics and efficacy testing.

In the current study, respondents indicated that anthelmintics were most frequently purchased in spring and autumn. This might reflect that owners are aware of the need to target treatments at specific times of year for tapeworm and encysted cyathostomin larvae (Stratford et al., 2014). For example, encysted cyathostomin larvae are undetectable by standard FEC methods and most anthelmintics (i.e. a single dose of benzimidazole, pyrantel compounds or ivermectin) that could be used to reduce strongyle egg shedding following FEC testing have relatively low efficacy against cyathostomin inhibited larvae (Matthews, 2008). It could also reflect that the amount of anthelmintic applied in summer is linked to the use of FEC testing to target treatments, where relatively high proportions of horses do not require anthelmintic administration because their FEC test result indicates that their egg shedding levels fall below the 200 eggs per gram treatment threshold. Although uptake of FEC testing has been relatively slow (Stratford et al., 2011), the level of uptake is now higher as indicated by the results here, where 76% of all respondents indicated that they already use testing to guide anthelmintic treatment decisions. The results here showed that veterinarian purchasers stated that their seller was most likely to recommend FEC testing, while pharmacist purchasers stated that their seller recommended this the least often. This could be a result of pharmacist purchasers being less engaged with these prescribers, indicated by the finding that they considered prescriber advice less than the other groups. It is possible that UK horse owners are obtaining advice and FEC test results prior to purchasing online from pharmacists as some of the larger equine FEC service providers perform parasite diagnostics but do not sell anthelmintics (for example, Westgate Laboratories, westgatelabs.co.uk, and Diagnosteq, www.liverpool.ac.uk/diagnosteq). Indeed, a ~10 respondents stated in the voluntary comments section that they relied on information provided directly by FEC service companies such as this before purchasing anthelmintics elsewhere. These responses

demonstrate the complexity in anthelmintic purchasing behaviours in the UK horse owning population.

Encouragingly, analysis of the survey results showed that most respondents stated that they practiced dung removal from pasture to reduce parasite contamination. This practice has been demonstrated previously to substantially reduce the level free-living parasitic larval stages in the environment (Herd, 1986; Corbett et al., 2014) and, as a consequence, reduce the frequency of anthelmintic treatments and, presumably, selection pressure for drug resistance. Regardless of from whom, or how, owners purchased anthelmintics, it would appear that the horse owner respondents here are aware of the benefits of this important method of equine helminth control.

Those owners who purchased anthelmintics online most often stated that they received little or no advice at the point of purchase. This group of owners were more likely to view online sources of information as important and were less likely to have 'appropriate anthelmintic for the parasites being treated' raised by their anthelmintics' supplier. Against this background, high proportions of the online-purchasing group still stated that they implemented a variety of best practice strategies (weighing before dosing, ensuring that the full dose is swallowed, applying quarantine treatments), indicating that they were aware of these procedures, despite an apparent lack of seller/purchaser interaction at the point of purchase. The favourable view toward veterinarians by the online purchaser group could be due to the fact that individuals may receive 'free' advice from veterinarians before purchasing cheaper products online (Kaplan, 2013). The lack of transparency in some online interactions was indicated by a self-directed search by these authors of 30 UK online anthelmintic sellers that revealed that the classification of the prescriber was rarely explicit. This might go some way to explaining the relative lack of interaction between horse owners

and prescribers utilising this mode of sale. The complexity of internet veterinary medicine sales was further outlined in an article published based on recent findings from the UK Veterinary Medicines Directorate in which the illegal purchase and sale of veterinary medicines by pet owners, including horse owners, was highlighted (Woodmansey, 2016). In this article, both the re-sell by owners of a previously purchased POM-V product (the majority of which were dewormers and flea products) was described, along with the illegal purchase of products from non-UK based companies. Indeed, the Veterinary Medicines Directorate cited one case where they wrote to 3,500 customers who were electronically purchasing illegal products from a French-based company, with > 70% of these customers subsequently stating that they were 'completely unaware' that they had made an illegal purchase. These findings serve to emphasise the difficulty in appropriately monitoring responsible prescribing of veterinary medicines via internet sales.

In summary, the findings here indicate that most horse owning respondents stated that they implement best practice helminth control principles. However, in the case of those who predominantly purchased through pharmacists and/or via the online route, the results suggest that these individuals are more concerned with personal preferences and value prescriber advice less. This suggests that those who are not receiving direct (face-to-face, telephone) advice from a knowledgeable prescriber must be encouraged to engage more in the principles of best practice control (Sallé and Cabaret, 2015). This could be achieved through the introduction of mandatory guidelines to be followed by all prescribers at the point of purchase and/or the closer monitoring of the quality of advice pertaining to all anthelmintic sales. Or even, simply, providing better basic advice on all internet selling sites so that horse owners have to, or have the option to, read relevant information prior to the purchase of anthelmintics.

Conflict of Interest

There were no conflicts of interest in the implementation of this project.

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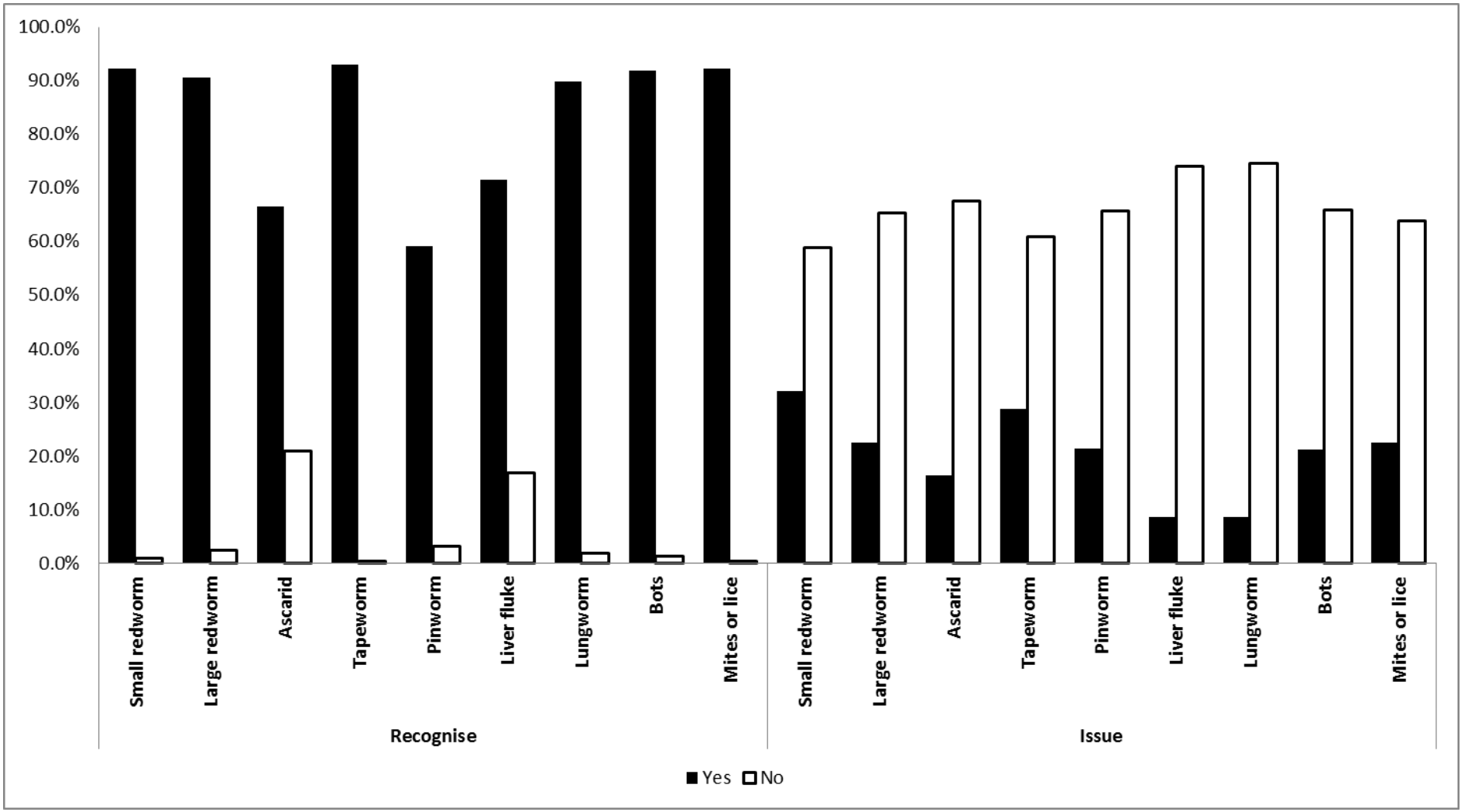
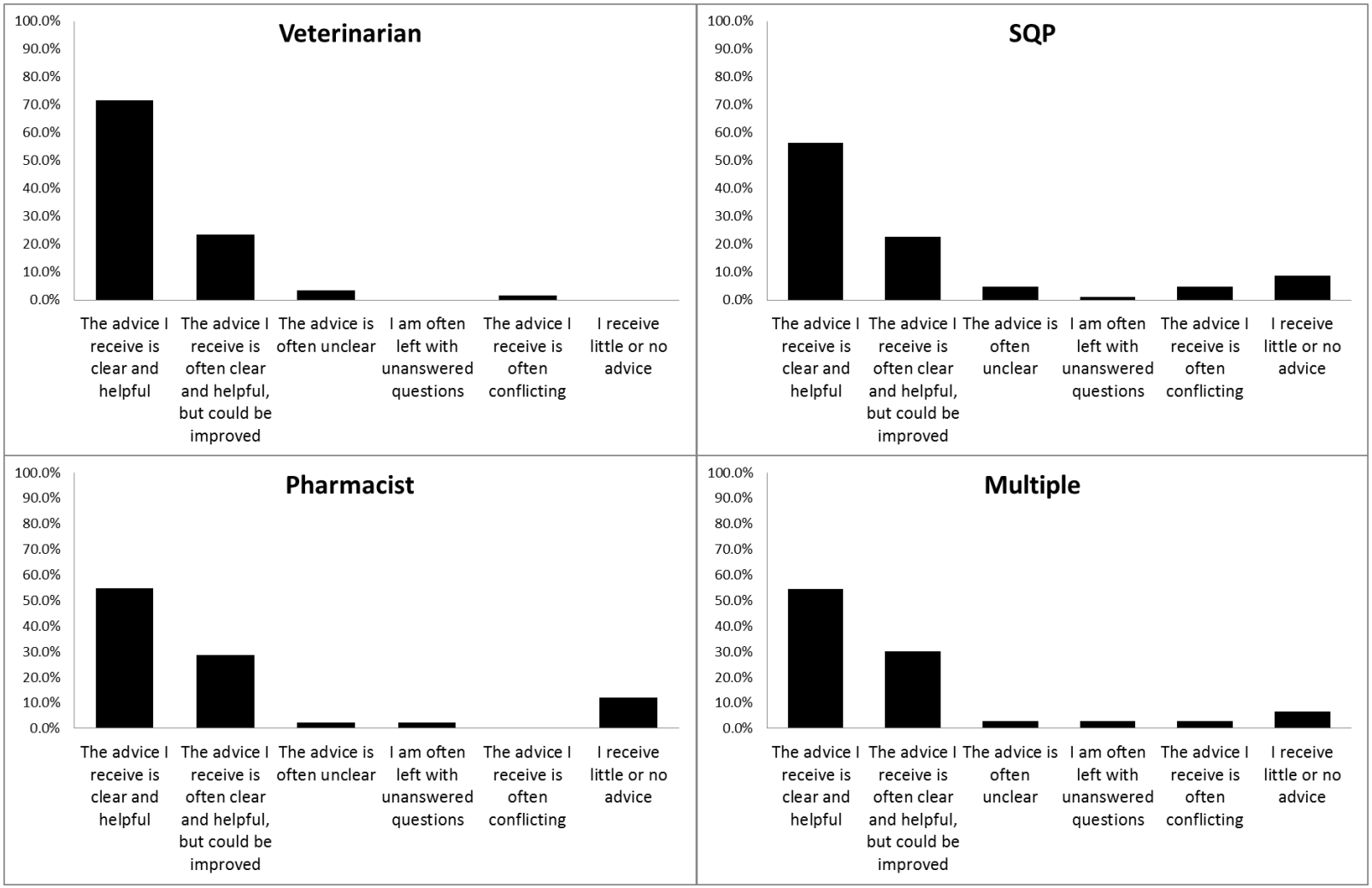
Figure 1. Details of respondents' recognition of helminth names and consideration of which helminths are an issue. Proportions are representative of participants who selected 'yes' or 'no'. Participants who failed to answer are not represented.



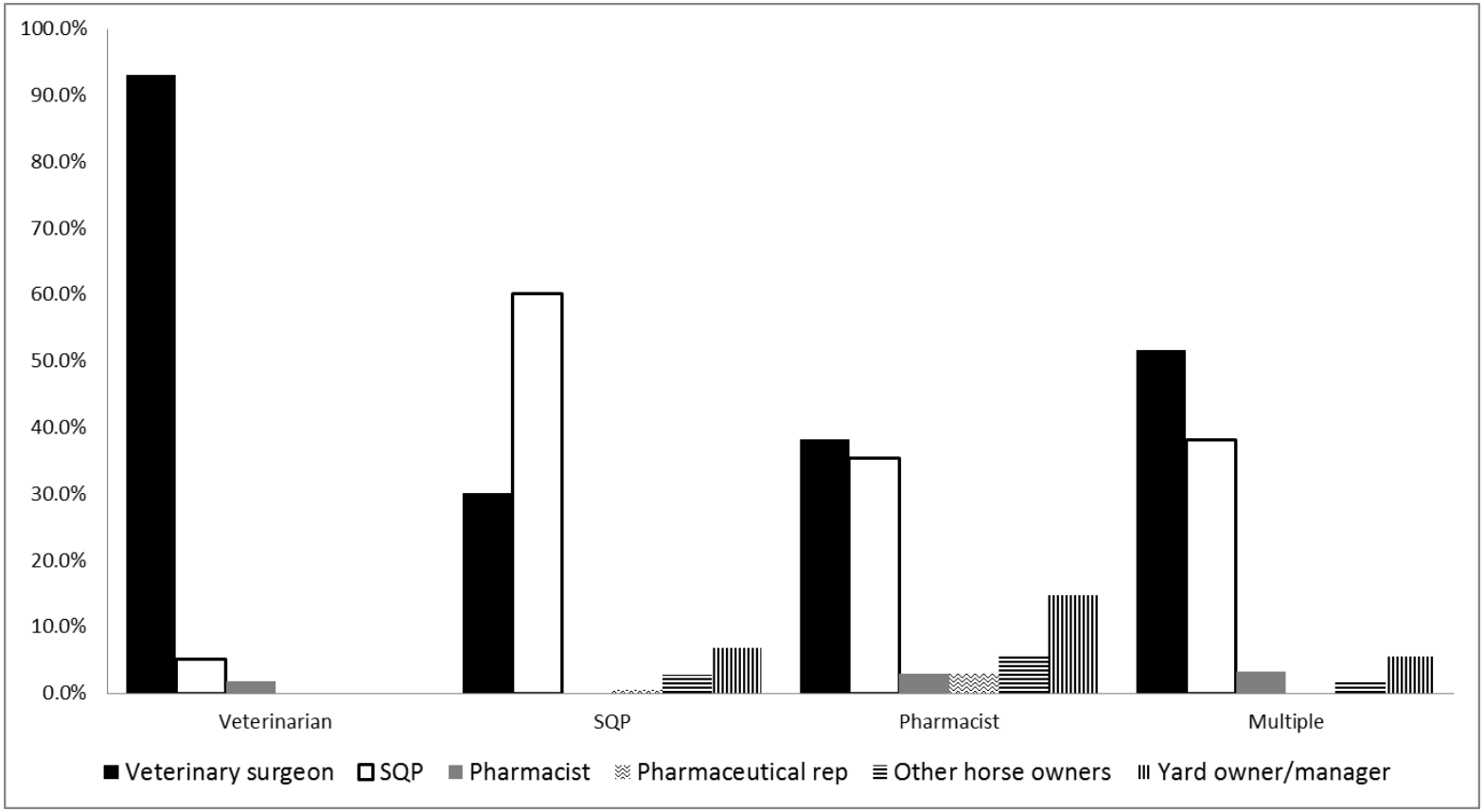
Outcome % - proportion of total participants (n=687)

Figure 2. Responses to **Question 18**: ‘Regarding the quality of advice you receive on anthelmintic use, which statement most closely reflects your experience?’ by channel.



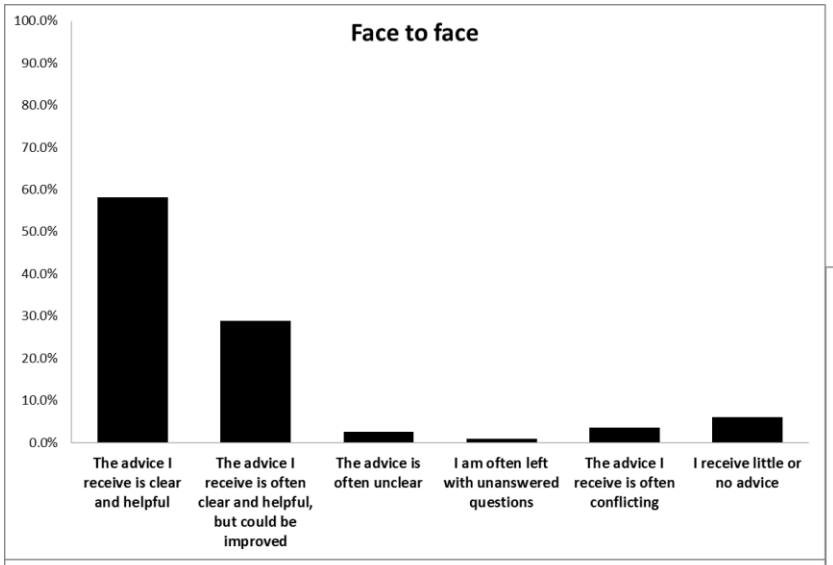
Outcome % - proportion of total participants who provided an answer to survey question

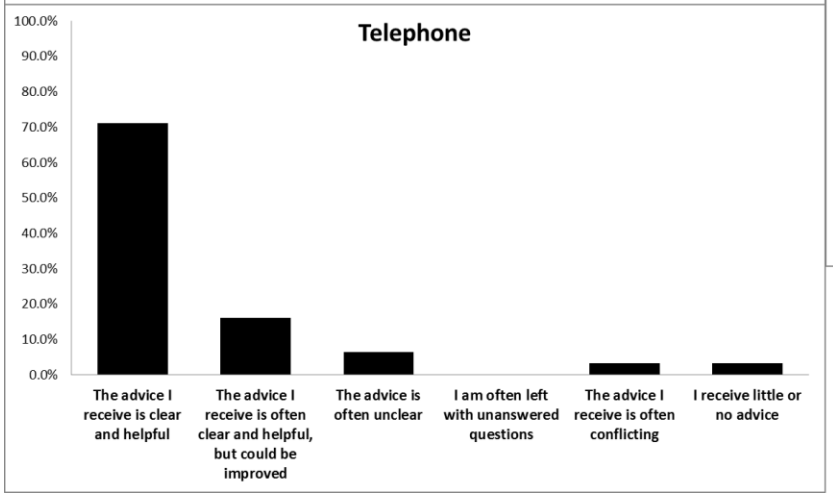
Figure 3. Responses to Q21: 'Which of the following most influences the anthelmintics you use?' by channel.

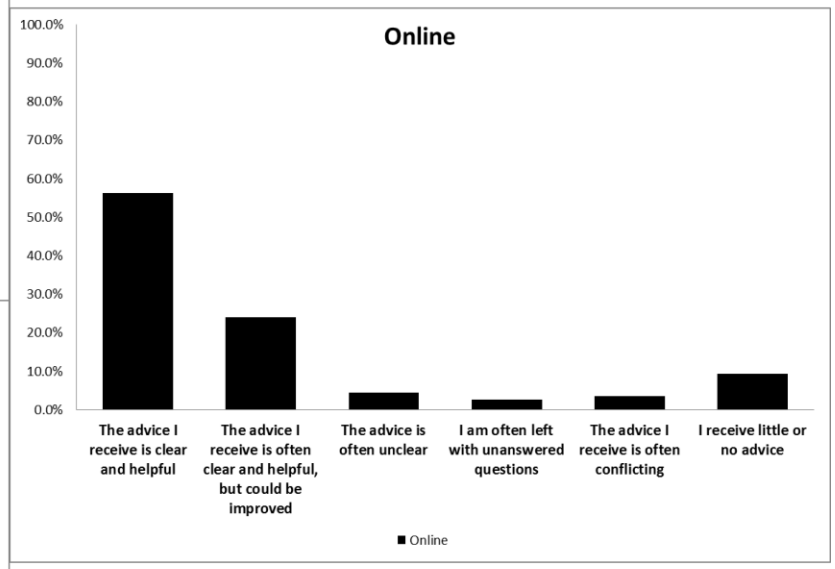


Outcome % - proportion of total participants who provided an answer to survey question

Figure 4. Details of responses to ‘Q18) Regarding the quality of advice you receive on anthelmintic use, which statement most closely reflects your experience’ survey question by purchase method.







Outcome % - proportion of total participants who provided an answer to survey question

Table 1. Details of responses to the demographic questions.

Demographics	**Horse owners (n=687)**	
	% proportion of total who began survey	n number of responses to each option on the question
Location		
1 (Scotland)	8.3	57
2 (N. England)	16.2	111
3 (N. Ireland)	1.0	7
4 (Wales)	3.6	25
5 (Midlands)	12.5	86
6 (SE England)	51.4	353
7 (SW England)	6.3	43
ǂ	0.0	0
Gender		
Male	2.6	18
Female	96.5	663
ǂ	0.9	6
Age		
A (18-29)	16.9	116
B (30-39)	24.5	168
C (40-49)	23.9	164
D (50-59)	24.2	166
E (60+)	9.9	68
ǂ	0.7	5
Purchase anthelmintic		
Yes	90.1	619
No	7.9	54
ǂ	2.0	14
Administer anthelmintic		
Yes	91.0	625
No	4.7	32
ǂ	4.4	30
Accommodation		
Livery yard	43.4	298
Riding school	36.1	248
Studfarm	0.1	1
Racing stable	1.5	10
Own property	2.0	14
ǂ	16.9	687

ǂ Participant did not provide information

Table 2. Responses to **Question 13: '**Who do you purchase your anthelmintics from?' and **Question 14: '**How do you normally buy anthelmintics?'

Purchase channel (n=494)		
	% (proportion of total participants who provided an answer)	n (number of responses to each option on the question)
Veterinarian	12.1	60
Suitably qualified person	51.8	256
Pharmacist	8.5	42
> 1 channel	27.5	136
Purchase route (n=494)		
Face-to-face	47.4	234
Telephone	6.3	31
Online	45.7	226
ǂ	0.6	3

ǂ Participants that did not provide information

Table 3. Responses to **Question 17**: 'What do you view as important when purchasing anthelmintics?', by purchase channel. Chi square comparison of responses across all groups were conducted and p-values are reported here.

Question 17 statements	Veterinarian						SQP						Pharmacist						Multiple channels						p-value
	Important		Neutral		Not important		Important		Neutral		Not important		Important		Neutral		Not important		Important		Neutral		Not important		
By purchase channel	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	%	n/ t	
Convenience	48.0	24/ 50	28.0	14/ 50	24.0	12/ 50	64.6	153/ 237	24.1	57/ 237	11.4	27/ 237	65.9	27/ 41	26.8	11/ 41	7.3	3/ 41	54.2	71/ 131	32.8	43/ 131	13.0	17/ 131	0.07
Time	36.2	17/ 47	34.0	16/ 47	29.8	14/ 47	47.4	108/ 228	37.8	86/ 228	14.9	34/ 228	45.0	18/ 40	42.5	17/ 40	12.5	5/ 40	37.1	46/ 124	47.6	59/ 124	15.3	19/ 124	0.09
Cost	47.1	24/ 51	35.3	18/ 51	17.7	9/ 51	71.0	171/ 241	21.6	52/ 241	7.5	18/ 241	77.5	31/ 40	20.0	8/ 40	2.5	1/ 40	68.5	89/ 130	25.4	33/ 130	6.2	8/ 130	0.01
Customer service	63.9	30/ 47	27.7	13/ 47	8.5	4/ 47	51.7	119/ 230	35.2	81/ 230	13.0	30/ 230	43.2	16/ 37	37.8	14/ 37	18.9	7/ 37	52.8	67/ 127	36.2	46/ 127	11.0	14/ 127	0.5
Time to talk with the supplier	68.1	32/ 47	25.5	12/ 47	6.4	3/ 47	37.8	87/ 230	37.8	87/ 230	24.4	56/ 230	22.9	8/ 35	48.6	17/ 35	28.6	10/ 35	41.1	51/ 124	41.9	52/ 124	16.9	21/ 124	0.001
Supplier's knowledge of the equids	94.2	49/ 52	3.9	2/ 52	1.9	1/ 52	59.6	140/ 235	23.0	54/ 235	17.5	41/ 235	46.0	17/ 37	32.4	12/ 37	21.6	8/ 37	66.9	85/ 127	24.4	31/ 127	8.7	11/ 127	<0.001
Supplier's knowledge of the parasites	96.2	50/ 52	1.9	1/ 52	1.9	1/ 52	67.4	163/ 242	19.0	46/ 242	13.6	33/ 242	48.7	18/ 37	32.4	12/ 37	18.9	7/ 37	77.2	98/ 127	14.2	18/ 127	8.7	11/ 127	<0.001
Supplier's knowledge of the anthelmintics	96.2	50/ 52	1.9	1/ 52	1.9	1/ 52	69.0	167/ 242	19.0	46/ 242	12.0	29/ 242	50.0	18/ 36	30.6	11/ 36	19.4	7/ 36	80.6	104/ 139	12.4	16/ 129	7.0	9/ 129	<0.001
Supplier's knowledge of anthelmintic resistance	96.2	50/ 52	1.9	1/ 52	1.9	1/ 52	67.4	163/ 242	21.5	52/ 242	11.2	27/ 242	51.4	19/ 37	29.7	11/ 37	18.9	7/ 37	78.3	101/ 129	14.7	19/ 129	7.0	9/ 129	<0.001
Supplier's knowledge of/expertise in parasite diagnostics	90.6	48/ 53	7.6	4/ 53	2.0	1/ 53	56.5	134/ 237	30.4	72/ 237	13.1	31/ 237	44.4	16/ 36	33.3	12/ 36	22.2	8/ 36	72.3	94/ 130	20.0	26/ 130	7.7	10/ 130	<0.001

Outcome % - proportion of total participants who provided an answer to survey question, (n/t) - number of individual responses to each option / total number answering survey question

Table 4. Responses to **Question 29:** 'Which of the following statements do you agree with when selecting anthelmintics?' by A. purchase channel and B. purchase route. Chi square comparison of responses across all groups were conducted and p-values are reported here.

Purchase channel	**Veterinarian**		**SQP**		**Pharmacist**		**Multiple channels**		p-value
Question 29 statements	%	n/ t	%	n/ t	%	n/ t	%	n/ t	
I do not usually require specific advice when purchasing anthelmintics	10.5	6/ 57	25.3	62/ 245	27.5	11/ 40	22.8	31/ 136	
I usually know which anthelmintic I require but sometimes require assurance or further guidance	61.4	35/ 57	62.5	153/ 245	65.0	26/ 40	65.4	89/ 136	0.01
I rely on the knowledge of the seller to ensure I am getting the correct product	28.1	16/ 57	12.2	30/ 245	7.5	3/ 40	11.8	16/ 136	

Purchase route	**Face-to-face**		**Telephone**		**Online**		
	%	n/ t	%	n/ t	%	n/ t	
I do not usually require specific advice when purchasing anthelmintics	17.9	41/ 229	20.7	6/ 29	29.0	63/ 217	
I usually know which anthelmintic I require but sometimes require assurance or further guidance	63.3	145/ 229	55.2	16/ 29	64.1	139/ 217	<0.001
I rely on the knowledge of the seller to ensure I am getting the correct product	18.8	43/ 229	24.1	7/ 29	6.9	15/ 217	

Outcome % - proportion of total participants who provided an answer to survey question, (n/t) - number of individual responses to each option / t number answering survey question

Table 5. Responses to **Question 22: '**When purchasing anthelmintics, how often are the following points raised by the seller?' by purchase channel. Chi square comparison of responses across all groups were conducted and p-values are reported here.

Question 22 statements	Veterinarian						SQP						Pharmacist						Multiple channels						p-value
	Always-Often		Sometimes		Rarely-Never		Always-Often		Sometimes		Rarely-Never		Always-Often		Sometimes		Rarely-Never		Always-Often		Sometimes		Rarely-Never		
By purchase channel	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	%	n/t	
Appropriate anthelmintic for targeting parasites	89.8	53/59	6.8	4/59	3.4	2/59	68.8	172/250	14.0	35/250	17.2	43/250	56.4	22/39	15.4	6/39	28.2	11/39	76.5	104/136	9.6	13/136	14.0	19/136	0.006
Weigh scales/girth tape for dose estimation	66.1	37/56	17.9	10/56	16.1	9/56	60.4	151/250	14.4	36/250	25.2	63/250	41.0	16/39	20.5	8/39	38.5	15/39	64.7	88/136	14.0	19/136	21.3	29/136	0.1
Ensuring correct dose	82.5	47/57	7.0	4/57	10.5	6/57	68.1	171/251	11.6	29/251	20.3	51/251	55.0	22/40	17.5	7/40	27.5	11/40	69.9	95/136	11.8	16/136	18.4	25/136	0.1
Quarantine	58.5	31/53	17.0	9/53	24.5	13/53	31.8	77/242	16.9	41/242	51.2	124/242	30.0	12/40	20.0	8/40	50.0	20/40	39.1	52/133	22.6	30/133	38.4	51/133	0.004
Correct storage	39.6	21/53	28.3	15/53	32.1	17/53	34.4	84/244	13.9	34/244	51.6	126/244	30.8	12/39	20.5	8/39	48.7	19/39	35.9	47/131	18.3	24/131	45.8	60/131	0.1
Anthelmintic resistance	72.7	40/55	18.2	10/55	9.1	5/55	46.1	113/245	20.4	50/245	33.5	82/245	46.1	18/39	20.5	8/39	33.3	13/39	50.0	67/134	23.1	31/134	26.9	36/134	0.01
Faecal egg count testing	79.7	47/59	10.2	6/59	10.2	6/59	54.4	136/250	18.8	47/250	26.8	67/250	33.3	13/39	25.6	10/39	41.0	16/39	58.8	80/136	19.9	27/136	21.3	29/136	0.001
Efficacy testing	64.8	35/54	16.7	9/54	18.5	10/54	41.2	100/243	19.3	47/243	39.5	96/243	23.7	9/38	29.0	11/38	47.4	18/38	42.5	57/134	20.9	28/134	36.6	49/134	0.006
Dung removal	65.5	36/55	12.7	7/55	21.8	12/55	45.3	112/247	15.8	39/247	38.9	96/247	39.5	15/38	15.8	6/38	44.7	17/38	42.3	62/134	20.9	28/134	32.8	44/134	0.07
Rotational grazing	64.8	35/54	14.8	8/54	20.4	11/54	41.2	101/245	17.1	42/245	41.6	102/245	38.5	15/39	18.0	7/39	43.6	17/39	45.1	60/133	16.5	22/133	38.4	51/133	0.07

Outcome % - proportion of total participants who provided an answer to survey question, (n/t) - number of individual responses to each option / total number answering survey questi

Table 6. Responses to **Question 30: '**Do you think new or future classes of equine anthelmintics should be available by veterinary prescription only?' and **Question 31:** 'Do you think that ALL equine anthelmintics (current and new products) should be available by veterinary prescription only?' by purchase channel and purchase method. Chi square comparison of responses across all groups were conducted and p-values are reported here.

Purchase channel	**Veterinarian**		**SQP**		**Pharmacist**		**Multiple channels**		p-value
Question 30 statements	%	n/t	%	n/t	%	n/t	%	n/t	
Yes	68.4	39/57	19.2	39/245	20.0	8/40	33.8	46/136	
No	14.0	8/57	59.6	146/245	50.0	20/40	44.1	60/136	<0.001
Unsure	17.5	10/57	21.2	52/245	30.0	12/40	22.1	30/136	
Purchase route	**Face-to-face**		**Telephone**				**Online**		
	%	n/t	%	n/t			%	n/t	
Yes	35.8	82/229	27.6	8/29			21.7	47/217	
No	42.8	98/229	48.3	14/29			56.2	122/229	0.01
Unsure	21.4	49/229	24.1	7/29			22.1	48/217	
Purchase channel	**Veterinarian**		**SQP**		**Pharmacist**		**Multiple channels**		
Question 31 statements	%	n/t	%	n/t	%	n/t	%	n/t	
Yes	56.1	32/57	10.2	25/245	5.0	2/40	16.2	22/136	
No	24.6	14/57	73.5	180/245	75.0	30/40	61.8	84/136	<0.001
Unsure	19.3	11/57	16.3	40/245	20.0	8/40	22.1	30/136	
Purchase route	**Face-to-face**		**Telephone**				**Online**		
	%	n/t	%	n/t			%	n/t	
Yes	23.6	54/229	24.1	7/29			8.8	19/217	
No	58.1	133/229	55.2	16/29			72.8	158/217	0.001
Unsure	18.3	42/229	20.7	6/29			18.4	40/217	

Outcome % - proportion of total participants who provided an answer to survey question, (n/t) - number of individual responses to each option / t number answering survey question