Management and horse-level risk factors for recurrent colic in the UK general equine practice population

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Summary

Reasons for performing study: Recurrent colic occurs frequently in the general horse population but little evidence exists about what factors place horses at greater risk of recurrent colic.

Aims: To quantify time-varying and non time-varying risk factors for recurrent colic among horses attended by first-opinion veterinary surgeons in NW England.

Methods: A nested case–control study was conducted on data from a prospective longitudinal cohort study of 127 horses recruited subsequent to an episode of medical colic. Data were collected on management and recurrent colic episodes at 4 monthly intervals by telephone questionnaires. All recurrent colic episodes were selected as cases; controls were unmatched and randomly selected from all horse time at risk. Data relating to the 30 days prior to the date of colic or control selection were used to determine exposure status. Multivariable logistic regression analyses were used to determine risk factors for recurrent colic.

Results: In total, 59 cases and 177 controls were included. The final model showed that horses that displayed crib-biting/windsucking (CBWS) (OR 10.1, 95% CI 2.5, 41.0) or weaving behaviour (OR 3.9, 95% CI 1.5, 10.1) had an increased risk of recurrence of colic. Increasing time at pasture reduced the risk of recurrence (OR 0.99, 95% CI 0.99, 1.0). A significant interaction was found suggesting the risk...
associated with CBWS may be modified by feeding fruit/vegetables, however further research is required before recommendations for feeding practices can be made.

**Conclusions and potential relevance:** This study suggests that sufficient access to pasture may be an important means of reducing recurrent colic risk. The behavioural risk factors highlight individuals who may be at increased risk of recurrent colic and whose colic prevention strategies should be carefully managed.

**Introduction**

Colic is a high priority health concern for horse-owners [1]. It occurs frequently and may result in the need for surgical intervention or the death of the horse [2, 3]. Whilst many colic cases are isolated episodes, recurrence is frequently reported (following both medical and surgical colic episodes) and has been identified as a frustrating problem to manage [4, 5]. In a previous study, the rate of recurrent colic in the general horse population was shown to be high at 50 episodes of recurrence per hundred horse-years-at-risk [6].

Previous epidemiological studies have identified factors associated with altered likelihood of colic. These have included season and a number of management and horse-level risk factors including; age and breed, crib-biting/windsucking (CBWS) behaviour, parasites, dietary type and feeding practices, exercise, stabling and access to pasture, access to water, transportation, vaccination, premises/owner factors and use of the horse [7]. These findings highlight the multifactorial nature of colic and horses that have suffered an initial colic episode have been shown to be at increased risk of further colic episodes [8, 9, 10, and 11].

At present, there is little evidence available of horse and management level risk factors associated with increased risk of recurrent colic. One study of horses seen by ambulatory veterinarians in Texas compared horses with recurrent colic with two control populations; horses with colic but no prior history of colic and horses without colic (or prior history of colic) [12]. Risk factors associated with recurrent colic were; previous abdominal surgery, age (> 8 years), feeding coastal grass hay, recent change in diet, low stocking density (<0.5 horses/acre), geldings and the Arabian breed. This study gave important indications of risk factors for recurrent colic, although due to the retrospective case-control study format, it was not able to
investigate temporal (time-varying) relationships between the exposures (e.g. management practices at that time) and risk of recurrent colic.

There is growing evidence to implicate a link between equine stereotypic behaviour and increased colic risk. Studies investigating both epiploic foramen entrapment colic [13] and Simple colonic obstruction and distention (SCOD) colic [11] found increased risk if the horse displayed CBWS behaviour. The temperament of the horse, especially if irritable and excitable has been suggested to be a risk factor for colic [14]. ‘Stress’ has also been implicated in equine gastric ulceration syndrome which may also present with chronic intermittent colic [15]. However, the link between behaviour and colic is likely not straightforward as horses who were easily frightened, excited, went off food when stressed or had an inquisitive nature were found to be at reduced risk in one study [16]. Objective measures of what constitutes ‘stress’ in the horse and how this translates into colic risk are subjects worthy of further research.

This study aimed to identify risk factors for recurrent colic (including those factors which may vary over time) among the veterinary-accessing general horse population. Hypotheses were that diet and management, particularly stabling, grazing and exercise; preventive health care (such as anthelmintic treatment and dentistry) and behavioural aspects influence the risk of recurrent colic.

Materials and Methods

Study design and data collection

A nested case-control design was used with cases and unmatched controls randomly selected from a previously described longitudinal cohort study [6]. Both veterinary attended (n=59) and owner reported (n=17) recurrent colic episodes were included.

In brief, the cohort study enrolled 127 horses recruited via first opinion equine veterinary surgeons in the North West of UK. These were horses that were diagnosed with colic and had responded to medical treatment. Clinical details of the recruitment colic and each subsequent colic episode were sought from the attending veterinary surgeon. Horses with a history of surgery for colic, those less than 6 months old and mares with foals at foot were excluded from the study.
Owners completed a baseline and 3 follow-up telephone questionnaires at approximately 4 month intervals. The baseline questionnaire collected data on the initial (recruitment) colic episode, the horses’ signalment, use and behaviour, prophylactic health care including vaccination, dentistry and deworming, and management practices including diet, turnout and exercise routine.

The follow-up telephone questionnaires captured data that could potentially change during the study period and recorded any further colic episodes. Information regarding behaviour was not measured during follow-up, as it was considered that this would change little over the course of the study. Participating owners were asked to notify the study team if their horse had any further episodes of colic (including any owner-reported colic episodes where a veterinary surgeon was not called). For each recurrent colic episode, a further questionnaire was completed to ascertain: the date of the colic, whether the recurrence satisfied the case definition, a description of the colic, treatment and outcomes and whether the owner had any hypotheses of cause and, what recommendations the attending veterinary surgeon had made.

Horses were censored if they died, had colic surgery or were lost to follow up. A nested case-control study using data collected from this longitudinal cohort was designed to analyse the effect of time-varying and non-time-varying variables occurring over the course of the study.

**Case definition**

Recurrent colic was defined as an episode of colic diagnosed by a veterinary surgeon or, behavioural signs of colic observed (in the case of owner reported colic), and which occurred more than 48 hours after a prior episode of colic on the *proviso* that the horse had been free from signs of colic, eating a normal diet and passing normal faeces for a full 48 hours. Behavioural signs suggestive of colic included one or more of the following signs; flank watching, pawing, kicking belly, rolling, violent rolling, repeated stretching as if to urinate, grinding teeth, flehemen/curling lip, sweating, flatulence, getting up and down/restless and other.

**Selection of cases and controls**
Data were extracted from the cohort study and used to determine the effect of time-varying and non time-varying variables occurring over the course of the year by examining exposures in the 30 day period prior to being a case or control.

All recurrent colic episodes (total n=59 of which 17 were owner reported episodes) were selected as cases and the data relating to 30 days prior to the colic episode were used to determine exposure status. Three controls per case were randomly selected from all horse-time at risk. All contributing time at risk was summated until the point of loss to follow up, colic surgery or death due to colic or other reasons. Two days from the recruitment episode, and 2 days subsequent to each episode of recurrent colic were excluded from time at risk (according to our case definition). Additionally, for each case of recurrent colic the 30 days prior to the colic could not be selected as control data as these were contributory days to the ‘case’ time at risk in line with other studies [11, 17].

From the remaining cumulative time at risk (44,301 days) [6] a list of computer generated random numbers were used to select 177 control horse days. Case horses could serve as controls before they became a case or when they were back ‘at risk’ and a horse could be selected as a control at more than one time point. The selected case and control days were transformed back into the corresponding dates for each horse and exposure variables recorded within the 30 days prior to this date were extracted.

Statistical analysis

Univariable analysis was conducted on all variables as listed in supplementary information (see supplementary information tables 1 & 2). Categorical and continuous variables were assessed using univariable logistic regression (Minitab 15). The functional form of the relationship between continuous variables and the outcome were tested for linearity using Generalised additive models (GAM) [18] and plotted using S-Plus 2000. In order to assess the effect of changes in management that occurred during the study (i.e. time-varying effects) data were extracted and recategorised. This included a change in: the time spent at pasture; the frequency of forage feeds; the frequency of concentrate feeds; time spent exercising and a change in stocking density between each of the follow up questionnaires. These variables
were recoded and defined categorically as follows: no change occurred, an overall increase and an overall decrease between follow ups.

Prior to model building, all variables were assessed for correlation using Spearman’s correlation coefficients. Any variables with p<0.2 were included in a multivariable logistic regression model built manually using stepwise backwards elimination (SPSS). Variables were retained if their exclusion resulted in a likelihood ratio test statistic (LRTS) of p<0.05 or if there was evidence of confounding. The resulting model was retested by forcing all variables (with p<0.2) back into the model. The effect of biologically plausible interaction terms was tested in the model. Finally a multi-level multivariable model was built incorporating a random effect term for ‘horse’ (as a number of horses had multiple colic events during the cohort) to assess clustering within horse and the effect on the parameters of the model (MLwiN Version 2.18 Centre for Multilevel Modelling, University of Bristol). Model fit was assessed using the Hosmer-Lemeshow test statistic [19]. The stability of the model and the influence of individual data points were explored by assessment of delta-beta values for each variable in the final model. All other analysis except for multi-level modelling was conducted in SPSS and Minitab.

Results

In total 59 recurrent colic episodes (including 17 owner reported episodes) and 177 controls were included. The median time to first episode of recurrence was 101 days (n = 43, min 2, max 404, IQ range 217 days). Three horses had a first recurrence within 7 days of the initial colic episode and seven horses had first recurrence within 30 days. There were 9 horses with 2 episodes of recurrence, 4 horses with 3 episodes, 2 horses with 4 episodes and 1 horse with 5 recurrent colic episodes during the course of the cohort. For further details of horse-time contributed to study see [6].

Tables 1 & 2 (within supplementary material) detail results of univariable analysis. A total of 47 variables were used to build the multivariable model. A multivariable logistic regression model (Table 1) showed that horses that displayed CBWS or weaving behaviours, had reduced time spent at pasture and were fed probiotics had
an increased risk of colic. The variable “fed probiotics” was borderline significant (p=0.055) and the overall fit of the model with the data was improved judging by the Hosmer-Lemeshow test statistic hence it was retained within the model but should be interpreted with caution.

Time spent at pasture (in hours per day per week) was found to approximate a linear relationship with the risk of recurrence. Although the odds ratio was small (0.99) this represents the change in risk of colic occurring per hour/day change in grazing over the course of a week. For example, compared to a horse that is always stabled, a horse with 12 hours/day/week access to pasture had almost half the risk (OR=0.43) of recurrent colic (Table 2).

There was a significant interaction between feeding fruit/vegetables and CBWS behaviour. This suggested that among horses that displayed CBWS behaviour, those also fed fruit/vegetables were at reduced risk of recurrent colic (OR = 0.15) compared to those that just demonstrated CBWS behaviour (OR=10.1) (see table 1 footnote).

A multilevel model, including horse as a random effect, showed there was no significant within-horse clustering and hence no effect on the other parameters within the model. Analysis of the delta beta distributions for the variables in the model found that the CBWS variable had one influential data point (>0.4 or – 0.4). This was a control horse and its removal resulted in a larger odds ratio for risk of CBWS (16.3, 95% CI 3.2, 82.4) in the model. The data for this horse were correct and therefore were retained in the final analysis.

Discussion

This study has identified a number of factors associated with altered risk of recurrent colic in the general horse population. Currently, there is little information on the temporality of risk factors (i.e. changes that occur over time) and recurrent colic. One study called for a ‘clearer definition of time relationships of events with colic’ in order that specific management recommendations could be made [8].

The use of a nested case-control design within a cohort study enabled particular time-varying and non time-varying exposures to be examined. In contrast to many previously published case-control studies on colic, the exposures were recorded
prospectively (i.e. prior to a horse having a recurrent colic episode). This creates some logistical disadvantages as data collection is time consuming and involves regular contact with participants throughout the study period, and losses to follow up may occur more frequently due to the extended nature of the study (although our participant retention rate was good 89.8%). However, these potential disadvantages are outweighed by the benefits of obtaining likely better quality of data as recall bias should be minimised. Using this type of study design, it was also possible to examine a specific time period prior to the recurrent colic episode. The findings of the present study builds upon those reported from the baseline survey [6] as it allows for the variability that occurs within the management of the horse over the course of a year and accounts for each individual episode of colic.

Horses that display CBWS behaviour have previously been shown to be at increased risk of medical colic and some types of surgical colic lesions [6, 11, 17 & 20]. The aetiology of this stereotypic behaviour is not fully understood and many hypotheses have been proposed including confinement within a stable [21], reduced access to pasture along with high concentrate and low forage diets [22], horse temperament, other stressors, genetics or a form of gastrointestinal dysfunction [17 & 23]. CBWS may not only be a marker for particular individuals that are prone to colic, it may have a direct physical influence upon colic aetiology or could be a proxy for other management factors involved in colic risk. Ultimately the link between CBWS behaviour and colic remains unclear and warrants further investigation.

This study is the first to report an association between weaving behaviour and increased risk of recurrent colic. Eleven (8.7%) horses among the cohort displayed this form of behaviour, 7 of which had a colic recurrence (63.6% of horses that weaved). Whereas CBWS behaviours are oral stereotypies, weaving is classed as a locomotor stereotypy and is likely to have different predisposing causes. Hypotheses of why horses may develop this behaviour include confinement within a stable, reduced opportunity for social contact or an anticipatory/frustration element [24 & 25]. One study found that the type and quantity of forage provided, bedding, yard size and tactile contact with neighbouring horses while stabled influenced the occurrence of weaving [21]. It may be that horses that weaved in our cohort had differing aspects of their general management compared to those that did not weave.
or that aspects of their management may be linked to both weaving and colic risk, although this is an area requiring further investigation.

Increasing time spent at pasture was found to be associated with a decreased risk of recurrent colic in the present study. This is in agreement with three previous studies investigating the risk of colic [11, 17 & 26] and may reflect the beneficial effects of grazing perhaps in combination with the ability to exercise and opportunities to interact with the natural environment. The equine gastrointestinal tract has evolved to be optimally adapted for trickle feeding and a forage based diet. Providing suitable access to pasture may go some way to meet these physiological requirements however additional attention may be required to ensure pasture is appropriately managed in order to balance out the management of colic risk and other medical conditions. This may include; pasture analysis to examine whether suitable grass types and other plant species are present, limiting parasitic exposure, and maintaining an appropriate stocking density as a few examples. Within this study, ‘access to pasture’ included only those horses that were turned out onto grass paddocks/fields and we found no association with acreage or stocking density and the risk of recurrence. Any change in the amount of time spent at pasture is likely to constitute a change in diet, itself a risk factor for colic. For this reason it is advisable that any changes are introduced slowly.

Feeding fruit and vegetables was found to be associated with a decreased risk of colic within this cohort although this finding should be interpreted with caution and may not be applicable to other populations. The exposure was recorded as a binary variable (feed fruit/veg yes/no) and it was not possible to assess the effect of frequency, type or quantity fed due to small numbers within the sample. Therefore it is not possible to make recommendations on how to incorporate fruit and vegetables into the diet to alter colic risk. One possibility is this may be a proxy measure for dietary practices of particular types of owners or other management factors not accounted for within these data. This finding requires additional research in order to understand the impact of feeding fruit and vegetables on colic risk in practice. One study investigating feeding preferences in horses found that some fruit and vegetable flavours increased the acceptance and rate of consumption of food [27]. If such feeding behaviour is interpreted by owners as the horse enjoying the food then this
may motivate some owners to provide such foods within the diet. Further work is warranted to examine dietary decisions made by different types of horse-owners and to understand the motivations behind feeding behaviours and their potential impact on equine health.

A significant interaction was found whereby the increased risk associated with CBWS was modified by additionally feeding fruit and vegetables. It may be for example that feeding fruit and vegetables is associated with particular management factors such as catching horses in the field, and the availability of turn out could potentially link this finding with CBWS although it is unclear from this data how to interpret this effect. This finding adds credence to the possible protective role of feeding fruit/vegetables reported above; however it is not possible to recommend how to incorporate these into the diet from this data. A Chi-square test indicated that those horses fed fruit/vegetables were no less likely to display CBWS behaviour than those not fed fruit/vegetables. Another study found a significant interaction between crib-biting and carer of the horse and proposed that this may be due to the way in which particular types of carers approach the management of horses [16]. It may be that carers differ in their motivations and decision making for the types of food offered to their horses and this may be influenced by their attitudes surrounding the needs of horses with CBWS behaviour.

The finding that probiotics may be associated with an increased risk of recurrent colic should be interpreted with caution. The confidence intervals cross one and this variable was not statistically significant (p=0.055) but its inclusion improved the overall fit of the model. It is possible that administering probiotics is a marker for certain types of horses that already have an inherent risk of colic e.g. older horses, those with dental problems, those prone to laminitis or with previous episodes of colic. There is little evidence on the effect of feeding probiotics on equine colic. Although not directly comparable to this study of an adult equine population (where a variety of different probiotics were used), one study reported the administration of Lactobacillus pentosus WE7 preparation to be associated with diarrhoea and signs of colic in foals [28]. Another study reported a beneficial effect with feeding probiotics to horses with acute enterocolitis leading to a reduction in hospitalisation time [29]. Nevertheless, questions remain about the efficacy of probiotic preparations and further clinical trials are required to investigate their therapeutic potential in horses.
especially as many preparations are available via the veterinary market [30] and appear popular among some owners.

One of the study limitations was that it was not possible to identify the cause of colic in most cases. This is commonly the case among medical colic treated in general practice with one study reporting 72% of colic cases seen over 2 years were spasmodic/undiagnosed colic [3]. The underlying cause of such undiagnosed colic may be multifactorial with a range of presentations [31]. It is possible that misclassification bias may have been introduced where owner reported colic cases were included in the analysis. However, all further episodes of colic (or suspected colic for the owner reported episodes) were assessed according to whether the described episode fitted the case criteria for colic (as outlined within the methods). It was considered that the combination of the fulfilment of the case criteria, assessment of the reported signs of colic (see [6] for further details) along with the owners’ experience of a veterinary diagnosed medical colic would improve the assumption that these owner reported colic episodes were correctly reported in order to reduce this potential bias. Within this study we did not find an association with exercise (type or frequency) and the risk of recurrence. Additionally, we did not collect blood or faecal samples from this cohort for parasitological investigations. Previous studies have suggested a link between gastrointestinal parasites (e.g. tapeworm associated colic [32] or more rarely, thromboembolic disease / verminous arteritis caused by Strongylus vulgaris [31] associated with recurrent colic). We measured factors that may be considered proxy measures for parasitic exposure such as use of anthelmintic products (frequencies and types); pasture management approaches, stocking density, co-grazing and some exploration of how owners decide upon approaches to parasite control. However, none of these factors were influential in the final model.

**Conclusions and practical relevance**

Horses that have experienced a colic episode are known to be at increased risk of future episodes. In this study we report risk factors that provide further evidence to support managemental approaches to colic prevention namely the provision of access to grazing. The behavioural risk factors identified (CBWS and weaving) highlight individual horses that may be at higher risk for recurrent colic and therefore it would seem appropriate that particular attention is paid to their colic prevention strategies.
(e.g. diet, access to grazing, anthelmintic prophylaxis and dental care). Further studies to investigate the mechanisms by which these behaviours influence the risk of colic are warranted.

**Table 1: Multivariable logistic regression model of risk factors associated with recurrence of colic in the general horse population in North West England**

<table>
<thead>
<tr>
<th>Category</th>
<th>Odds ratio</th>
<th>Lower 95% confidence interval</th>
<th>Upper 95% confidence interval</th>
<th>Likelihood ratio p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crib-biting or windsucking (CBWS) behaviour</td>
<td>No (Ref) 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10.1</td>
<td>2.5</td>
<td>41.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weaving behaviour</td>
<td>No (Ref) 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3.9</td>
<td>1.5</td>
<td>10.1</td>
<td>0.004</td>
</tr>
<tr>
<td>Time spent at pasture (hours per day / week)</td>
<td>0.99</td>
<td>0.99</td>
<td>1</td>
<td>0.005</td>
</tr>
<tr>
<td>Fruit / vegetables in diet</td>
<td>No (Ref) 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0.5</td>
<td>0.2</td>
<td>1.3</td>
<td>0.16</td>
</tr>
<tr>
<td>Probiotics in diet</td>
<td>No (Ref) 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.4</td>
<td>0.99</td>
<td>6.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Interaction term: Windsucking x fruit/vegetables in diet</td>
<td>0.03</td>
<td>0.002</td>
<td>0.5</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Based on 56 cases and 159 controls. Hosmer-Lemeshow test statistic p=0.446.

Ref=Reference category

Explanation of interaction term

- No fruit/vegetables and horse does not display CBWS behaviour, OR = 1
- No fruit/vegetables and horse displays CBWS behaviour, OR = 10.1
- Yes fruit/vegetables and horse does not display CBWS behaviour, OR = 0.5
- Yes fruit/vegetables and horse displays CBWS behaviour, OR = (10.1 x 0.5 x 0.03) = 0.15

**Table 2: Decreasing risk of recurrent colic with time spent at pasture**

<table>
<thead>
<tr>
<th>Time spent at pasture</th>
<th>Number of hours per week</th>
<th>Odds ratio of risk of recurrent colic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours / day / week</td>
<td>Count</td>
<td>Probability</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>1 hour / day / week</td>
<td>7</td>
<td>0.93</td>
</tr>
<tr>
<td>3 hrs / day / week</td>
<td>21</td>
<td>0.81</td>
</tr>
<tr>
<td>6 hrs / day / week</td>
<td>42</td>
<td>0.66</td>
</tr>
<tr>
<td>12 hours / day / week</td>
<td>84</td>
<td>0.43</td>
</tr>
<tr>
<td>24 hours / day / week</td>
<td>168</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**References**


[6] Detail to be provided upon acceptance.


Supplementary material

Table 1: Univariable results of risk factors associated with recurrence of colic (p<0.2).

Table 2: Univariable results of factors found to have no significant association with recurrence of colic (p-value>0.2)