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Case control study to identify risk factors for simple colonic obstruction and distension colic in horses

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Summary

A case control study was performed to identify risk factors for colic caused by simple colonic obstruction and distension (SCOD) in the horse. Case horses were recruited from 2 veterinary school clinics. Control horses were population based and matched by time of year. A number of risk factors were considered in the following areas: general carer and premises information; exercise information; husbandry information (housing- and pasture-related); feeding information; breeding information; behavioural information; travel information; preventive medicine information and previous medical information. All variables with a P value of <0.2 in the univariable analysis were considered for possible inclusion in a multivariable model. A final model, produced by a forward stepwise method, identified crib-biting or windsucking, an increasing number of hours spent in a stable, a recent change in a regularexercise programme, the absence of administration of an ivermectin or moxidectin anthelmintic in the previous 12 months and a history of travel in the previous 24 h as associated with a significantly increased risk of SCOD. An alternative final model, produced by a backwards elimination method, identified the same variables as the forward model with, in addition, a history of residing on the current establishment for less than 6 months, a history of a previous colic episode and the fewer times per year the teeth were checked/treated as associated with a significantly increased risk of SCOD. Three of the risk factors in this model were associated with a large increase in risk: stabling for 24 h/day, crib-biting/windsucking and travel in the previous 24 h.

Introduction

Previous epidemiological studies have identified risk factors associated with the development of colic in the horse (Tinker *et al.* 1994, 1997; Cohen *et al.* 1995, 1999; Cohen and Peloso 1996; Reeves *et al.* 1996; Kaneene *et al.* 1997; Hillyer *et al.* 2001; Traub-Dargatz *et al.* 2001). In particular, they attempted to identify management or alterable risk factors, knowledge of which should allow a reduction in the colic incidence in the overall horse population. These previous studies have often produced conflicting results in respect of the impact of individual risk factors. This may be a result of differences in the study designs of the previous reports and their regional distribution (Reeves 1997). However, it has been suggested that differences may result from the use of equine colic, of any type, as a general disease outcome rather than a more specific diagnosis (Reeves *et al.* 1996). There has only been one recent epidemiological investigation of a specific colic diagnosis but this study compared the diagnosis of enterolithiasis with other cases of colic rather than the background horse population (Cohen *et al.* 2000). The aim of this study was to investigate risk factors in comparison to the general horse population for the occurrence of a more specific type of colic.

Materials and methods

Case definition

The case definition was a horse showing signs of colic attributable to a simple obstruction, with subsequent distention, of the large colon (simple colonic obstruction and distension SCOD). The cases were identified by a small number of clinicians (MHH, FGRT, CJP, GBE) experienced in the diagnosis of horses with colic and the diagnosis made from results of clinical examination (including rectal examination, abdominal paracentesis and nasogastric intubation), clinicopathology, ultrasonography and laparotomy, as appropriate. Cases appropriate for inclusion included simple impaction of the pelvic flexure, simple left dorsal colon displacement (nephrosplenic entrapment), simple left colon displacement (retroflexion of the pelvic flexure) and simple right colon displacement. Cases with obstruction and subsequent distension of the large colon associated with a vascular obstruction (strangulation) were excluded, as were any cases with intercurrent abdominal disease.

Throughout this study, the term ‘horse’ is used to include all equidae and the term ‘recent’refers to the previous 4 week period prior to the SCOD episode (cases) or interview (controls).

Case and control selection

Cases were consecutively identified from horses admitted to the Universities of Bristol and Liverpool Veterinary Schools. All

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selected cases were included in the study. At time of admission and treatment of the selected cases, owners were informed that they would subsequently be contacted by telephone to complete a questionnaire. No further information about the details of the questionnaire was given.

Control horses (2 per case) were selected by selecting randomly an owner/carer from those who had brought a horse to the same Veterinary School in the previous calendar year. This carer was then contacted and the control horse selected randomly from those horses under their care. Potential control horses were excluded if they had shown signs of colic in the previous 4 weeks or if they were horses which would not be taken to the Veterinary School as a referral for colic if it was suggested by the attending veterinary surgeon. In this instance another horse with that carer was selected randomly or, if no other horses were available, a new control carer was randomly selected.

Questionnaire construction

Specific questions were constructed to allow the identification of potential risk factors. Areas of interest were determined from historically implicated factors associated with colic, factors investigated in previous studies and factors considered of biological plausibility. Where possible questions were developed to collect data in a similar way to earlier studies so that comparison of the results between studies might be possible. Questions related to recent history were confined to a period of the last 4 weeks (or the 4 weeks prior to the colic episode), for more general questions a period of the previous 12 months was selected. For the cases, the period of interest was until the first signs of colic were noticed and did not include any events that occurred subsequently.

The questionnaire was divided into sections: general carer and premises information; exercise information; husbandry information (housing-related); husbandry information (pasture-related); concentrate feeding information; forage feeding information; breeding information; temperament and behavioural information; travel information; preventive medicine information (dental- and parasite-related) and previous medical information. The case and control questionnaires were identical.

Data collection

All questionnaires were delivered via telephone by one operator who was not involved with the diagnosis or treatment of the cases and had not had prior contact with the owner.

For the cases, the questionnaire was completed at least 48 h after the horse had been enrolled on the study. A concurrent design was used so that the control questionnaires were completed at the same time as the cases.

Power calculation

The number of cases required in the study (80) was determined *a priori* assuming a power of 80%, an exposure level among the controls of 20%, with a significance level set at 5% for detecting an odds ratio of 2.5 and with 2 controls for each case.

Validation

Internal validation of data from the questionnaire was performed by having several questions eliciting the same measurement at different places in the questionnaire. External validation could be performed only on the cases, for these data from the questionnaire were compared to data collected at the time of admission to the Veterinary School. Repeatability of the data collection technique was assessed by completing the questionnaire a second time, 2–5 days after the initial interview for a sample of respondents.

Analysis

Descriptive data: Descriptive data for horses from the 2 Veterinary Schools, were compared by the Kruskal-Wallis test for continuous variables and Chi-squared test for discrete variables.

Univariable analysis

Univariable conditional logistic regression and Mantel-Haenszel methods were used to investigate each of the variables in turn (EGRET)[1]. The study design was matched with reference to time and, therefore, the analysis was matched on the matching variable (riskset) with the outcome as a colic case. Odds ratios (OR) and 95% confidence limits (CI) were obtained using maximum likelihood methods. The likelihood-ratio test statistic was used to estimate Pvalues.

Continuous variable handling

Continuous variables were examined in their continuous state, centred around the mean or as derived polynomial or categorised variables. Categories were determined using quartiles, quintiles or biologically plausible limits. Each continuous variable and the derived ones were examined in the univariable analysis. The most statistically and biologically significant form of each variable was selected for the multivariable analysis.

Multivariable analysis

Variable selection: Variables with a P value <0.2 were identified for possible inclusion in the multivariable analysis. For continuous variables and instances where multiple variables were measuring the same exposure the most appropriate variable for inclusion was selected according to biological and statistical significance.

Multivariable model construction: All the identified variables were fitted in a conditional logistic regression model (EGRET)[1] which took account of the matched study design. Both a backward and a forward stepwise approach to model construction were used. The backward stepwise (elimination) approach was used whereby all the variables were initially included and then variables with a P value of >0.1 were sequentially removed. For the forward stepwise inclusion model each of the potential variables were considered, and those with a P value of <0.05 were retained in the model. The 2 models were compared, and any variables appearing in only one model were re-assessed by examining the effect when they were forced into the other model. In addition, other manually selected variables were forced back into the model to check that no significant biologically plausible variables had been omitted. This resulted in the identification of 2 final models.

TABLE 1: Results of the univariable analysis of the general carer and premises information, exercise information and husbandry information - housing and pasture

Variable	n	Odds ratio	95% confidence interval	Wald P value	Likelihood ratio statistic P value
Current type of establishment					
Private stable	125	1.00			
Race training stable	13	2.29	0.74–7.03	0.149	
Livery stable	75	2.31	1.27–4.20	0.006	
Breeding stable	15	2.76	0.94–8.12	0.065	0.019
No. of horses resident at establishment					
1–3 horses	52	1.00			
4–7 horses	51	2.69	1.08–6.72	0.034	
8–15 horses	57	3.09	1.21–7.86	0.018	
>15 horses	68	3.91	1.60–9.57	0.003	0.012
No. of people caring for horse on a daily basis					
One person	66	1.00			
More than 1 person	162	2.08	1.01–4.31	0.048	0.039
Current occupation					
All other occupations	211	1.00			
Showjumping	17	4.80	1.69–13.63	0.003	0.002
Breed					
Non-Welsh pony	28	1.00			
Thoroughbred	44	3.03	1.03–8.93	0.045	
Thoroughbred-cross	63	2.78	0.99–7.80	0.052	
Welsh and Welsh-cross pony	30	0.94	0.28–3.22	0.925	
Arabian and Arabian-cross	20	0.89	0.20–3.93	0.873	
Non-Thoroughbred horse	43	1.28	0.40–4.03	0.679	0.027
Height					
Height (inches)	228	1.06	1.01–1.11	0.010	0.004
Recent exercise routine					
No regular exercise	83	1.00			
Regular exercise	107	0.83	0.42–1.62	0.583	
Regular exercise with a change in routine	38	10.14	3.72–27.68	<0.001	<0.001
No. of days since a change in exercise routine					
1–7 days	24	1.00			
8–14 days	12	0.09	0.01–0.95	0.045	
15–28 days	2	0.04	0.01–1.36	0.074	
More than 28 days	190	0.02	0.01–0.17	<0.001	<0.001
No. of h/day spent in stable in last 4 weeks					
Hours in stable	228	1.10	1.05–1.15	<0.001	<0.001
No. of h/day spent in stable in last 4 weeks					
0–6 h	49	1.00			
7–12 h	12	2.19	0.33–14.63	0.418	
13–18 h	67	5.10	1.67–15.59	0.004	
19–24 h	100	7.58	2.46–23.34	<0.001	<0.001
Recent change in daily housing routine					
No	184	1.00			
Yes	44	9.10	4.02–20.60	<0.001	<0.001
Recent change in number of h/day in stable					
No change	184	1.00			
Increased hours	33	13.64	4.78–38.93	<0.001	
Decreased hours	11	3.14	0.76–13.00	0.115	<0.001
Bedding currently used in stable					
Straw or hemp	74	1.00			
Shavings or woodchips	94	0.67	0.36–1.26	0.210	
Sawdust	3	0.62	0.05–7.39	0.707	
Paper or mats	13	0.16	0.03–0.85	0.032	
No stable access	44	0.07	0.02–0.27	<0.001	<0.001
Regular access (>3 x weekly) to pasture in last 4 weeks					
No	39	1.00			
Yes	189	0.34	0.15–0.82	0.016	0.012
Time since last had regular pasture access					
Currently has pasture access	190	1.00			
Last access <6 months ago	24	1.90	0.71–5.09	0.205	
Last access 6+ months ago	14	10.56	2.17–51.28	0.003	0.002

TABLE 2: Results of the univariable analysis of the concentrate and forage feeding information

Variable	n	Odds ratio	95% confidence interval	Wald P value	Likelihood ratio statistic P value
Total amount of concentrates fed/day in last 4 weeks					
0–4 lbs	100	1.00			
More than 4 lbs	128	2.76	1.42–5.35	0.002	0.002
Recent change in concentrate feeding					
No concentrate fed	29	1.00			
Concentrate fed with no change	168	1.82	0.69–4.80	0.223	
Concentrate fed with a change	31	7.90	2.37–26.36	<0.001	<0.001
Time of change in concentrate feeding					
Concentrate not fed or no change in last 4 weeks	195	1.00			
Change 1–7 days ago	15	12.03	2.66–54.44	0.001	
Change 8–14 days ago	14	3.01	1.02–8.92	0.047	
Change 15–28 days ago	4	0.67	0.07–6.41	0.726	<0.001
Recent change in coarse mix feeding					
No	107	1.00			
Yes	14	5.07	1.56–16.55	0.007	
Coarse mix not fed	107	1.04	0.58–1.85	0.900	0.014
Recent forage feeding					
No forage fed	32	1.00			
Forage fed	196	20.71	2.75–155.95	0.003	<0.001
Recent change in forage feeding					
Forage fed with no change	168	1.00			
Forage fed with a change	28	5.02	1.99–12.67	<0.001	
No forage fed	32	0.07	0.01–0.53	0.010	<0.001
Time of change in forage feeding					
Forage not fed or no change in last 4 weeks	202	1.00			
Change 1–7 days ago	12	22.00	2.84–170.41	0.003	
Change 8–14 days ago	12	4.88	1.28–18.60	0.020	
Change 15–28 days ago	2	2.00	0.13–31.98	0.624	<0.001
Recent change in dry hay feeding					
No	71	1.00			
Yes	13	6.73	1.72–26.38	0.006	
Dry hay not fed	144	1.01	0.55–1.87	0.965	0.006
Time of change in dry hay feeding					
Dry hay not fed or no change in feeding in last 4 weeks	215	1.00			
Change 1–7 days ago	8	14.00	1.72–113.79	0.014	
Change 8–28 days ago	5	3.00	0.50–17.95	0.229	0.003

In the presence of a large number of variables for possible inclusion in the multivariable model, sub-models based on a common theme were initially built and then amalgamated into a composite final model (Reeves *et al.* 1996).

Evidence of confounding was examined for all of the variables from the final models. For each pair of potentially confounding variables, one was removed in turn and the resulting effect on the remaining variable's status in the model was assessed.

Post-fit analysis of the final model was used to identify outlying data points. The stability of each of the final main effects variables was examined by analysis of the delta-betas. The delta-betas are an approximation of the amount that an estimated regression parameter would change if a given observation was omitted from the dataset. Thus a set of delta-betas includes, for every observation used, a value for every parameter estimated by the model (Pregibon 1981). In this way, the delta-betas are a means of determining the influence of each individual observation on the fit of the model. The fitted probability values were used to assess the accuracy of the models in predicting each of the cases and controls. The sensitivity and specificity of the final models were determined at various cut-off levels for the fitted probability values. Any effect of the individual diagnoses making up the SCOD case definition was also examined.

Results

Descriptive

The study period ran from March 1999 to November 2001. During this period 76 cases were identified and were all included in the study. For the controls 157 owners were selected randomly and contacted, of these 5 were not able to complete the questionnaire as a result of not having enough time or no longer having a horse. Cases were identified throughout the study period, although there was a trend for more cases in the spring and autumn.

Within the 76 cases (and their controls), 47 cases (and their controls) were from the University of Bristol and 29 cases (and their controls) from the University of Liverpool. No significant differences were found in age, sex, height or occupation of the horses from each of the Veterinary Schools. In addition, there were no significant differences in the establishment type or the main carer of the horse between the 2 Veterinary Schools. Within the 76 cases of SCOD, there were 29 cases of simple pelvic flexure impaction, 13 of simple left dorsal colonic displacement, 13 of simple left colonic displacement and 21 of simple right colonic displacement.

TABLE 3: Results of the univariable analysis of the breeding information, temperament and behavioural information, travel information, preventive medicine information (dental- and parasite-related) and previous medical information

Variable	n	Odds ratio	95% confidence interval	Wald P value	Likelihood ratio statistic P value
Carer describes horse's temperament as nervous					
No	210	1.00			
Yes	18	2.68	1.01–7.09	0.048	0.046
Horse displays crib-biting or windsucking behaviour					
No	192	1.00			
Yes	36	70.00	9.59–510.96	<0.001	<0.001
Recent frequency of transportation					
Horse has not travelled	143	1.00			
Horse travelled once	25	2.40	1.01–5.68	0.047	
Horse travelled more than once	60	1.06	0.55–2.04	0.866	0.131
Recent timing of transportation					
Horse not travelled in previous 24 h	213	1.00			
Horse travelled in previous 24 h	15	3.34	1.11–10.06	0.032	0.028
Time since teeth were last checked/treated					
Number of weeks since teeth checked/treated	228	1.02	1.00–1.03	0.037	0.025
Recent worming history					
Horse not wormed in previous 7 days	207	1.00			
Horse wormed in previous 7 days	21	2.84	1.15–6.99	0.023	0.022
Use of a moxidectin anthelmintic in previous 12 months					
Not used	135	1.00			
Used	93	0.36	0.19–0.71	0.003	0.002
Use of an ivermectin or moxidectin anthelmintic in previous 12 months					
Not used	28	1.00			
Used	200	0.24	0.10–0.56	<0.001	<0.001
Lameness problem in previous 12 months					
No	183	1.00			
Yes	45	2.23	1.08–4.60	0.030	0.028
Recent lameness problem					
No	207	1.00			
Yes	21	10.86	3.17–37.15	<0.001	<0.001
Has horse previously suffered from colic requiring veterinary attention					
No	178	1.00			
Yes	50	4.65	2.31–9.36	<0.001	<0.001
Timing of last previous colic episode requiring veterinary attention					
No known colic episode previously	178	1.00			
Colic episode in previous 12 weeks	12	10.20	2.12–49.02	0.004	
Previous colic episode more than 12 weeks ago	38	3.82	1.79–8.16	<0.001	0.001

Validation

Internal validation of the data obtained from separate areas of the questionnaire showed good correlation (correlation coefficient >0.99) for responses to similar questions. No discrepancies were found in the descriptive data from the cases when compared to the hospital records at admission and questionnaire repeatability showed good correlation between the data obtained at original and subsequent interviews (correlation coefficient >0.99).

Univariable analysis

The significant results of the univariable analysis ($P<0.05$) for the general carer and premises information, exercise information and husbandry information are shown in Table 1. The significant results of the univariable analysis ($P<0.05$) for the concentrate and forage feeding information are shown in Table 2. The significant results of the univariable analysis ($P<0.05$) for the breeding information, temperament and behavioural information, travel information, preventive medicine information (dental- and parasite-related) and previous medical information are shown in Table 3.

Multivariable analysis

The following variables were shown to be associated with an increased risk of SCOD and were present in both final models: Crib-biting or windsucking, an increasing number of hours spent in a stable, a recent change in a regular exercise programme, the absence of administration of an ivermectin or moxidectin anthelmintic in the previous 12 months and a history of travel in the previous 24 h (Table 4). In addition, a history of residing on the current establishment for less than 6 months, a history of a previous colic episode and the fewer times per year the teeth are checked/treated were also identified as being associated with an increased risk of SCOD in the backwards elimination model (Table 4). The inclusion of these 3 variables had a marked effect on the estimated ORs and CIs for all other variables in the model suggesting strong confounding. However, with the exception of ivermectin and moxidectin use, all estimates were further from the

TABLE 4: Results of the multiple conditional logistic regression analysis of the factors found, by univariable analysis, to be associated with SCOD. Model 1 was fitted using a forward stepwise procedure, whereas model 2 was fitted using a backwards elimination procedure

	Cases (n)	Controls (n)	Odds ratio	95% confidence interval	Wald P value
Model 1[a]					
Crib-biting or windsucking behaviour present	35	1	89.46	8.98–890.69	<0.001
No. hours stabled per day			1.16	1.04–1.29	0.008
Recent regular exercise programme with no changes (compared to no regular exercise)	25	82	0.35	0.09–1.30	0.116
Recent regular exercise programme with a change in exercise (compared to no regular exercise)	30	8	9.30	1.68–51.40	0.011
Ivermectin or moxidectin used in previous 12 months	58	142	0.08	0.01–0.58	0.012
History of transport in previous 24 hours	9	6	17.48	2.16–141.35	0.007
Model 2[b]					
Crib-biting or windsucking behaviour present	35	1	203.90	10.55–3941.42	<0.001
No. hours stabled per day			1.26	1.07–1.48	0.005
Recent regular exercise programme with no changes (compared to no regular exercise)	25	82	0.20	0.03–1.37	0.102
Recent regular exercise programme with a change in exercise (compared to no regular exercise)	30	8	36.79	2.90–466.48	0.005
Ivermectin or moxidectin used in previous 12 months	58	142	0.09	0.01–0.86	0.036
History of transport in previous 24 h	9	6	203.42	5.98–6924.37	0.003
Resident on current premises for >6 months	57	127	0.07	0.01–0.60	0.015
History of previous colic episode	31	19	18.77	1.53–229.84	0.022
Number of times teeth are checked/treated per year			0.29	0.10–0.81	0.018

[a]Forwards stepwise model deviance 50.9771; Likelihood ratio test value 116.0120 on 6 degrees of freedom, P<0.001; [b]Backwards elimination model deviance 34.1051; Likelihood ratio test value 132.8839 on 9 degrees of freedom, P<0.001.

null value and Pvalues were reduced. Furthermore, the addition of these variables did not create any difficulty in model fitting and convergence was achieved after few iterations. The variables associated with the greatest increased risk of SCOD were the performance of crib-biting or windsucking behaviour, stabling for 24 h/day and a history of transport in the previous 24 h.

The sensitivity and specificity of the final backwards elimination model was very high and is shown for a range of fitted probability value cut-off points (Fig 1). At a fitted probability value cut-off of 0.3, the model had both a sensitivity and specificity greater than 90%, i.e. it correctly predicted more than 90% of the cases and controls.

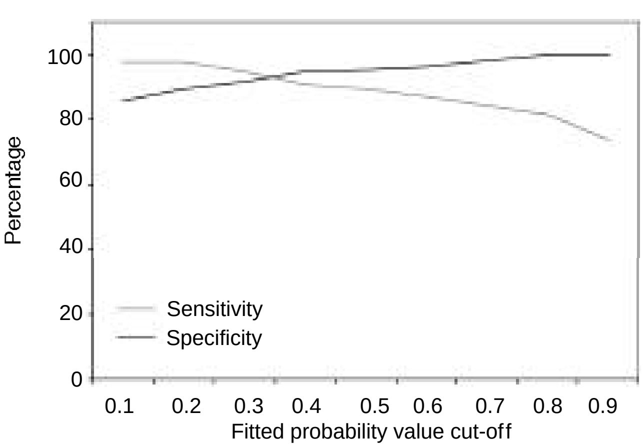

Fig 1: Graph showing the sensitivity and specificity of the final backwards elimination model in predicting case and control horses at various cut-off points for the fitted probability values.

Analysis of the fitted probability values from the cases in the final backwards elimination model identified those cases with a fitted probability value of less than 0.5 (n = 8). These included all of the individual diagnoses within the SCOD group with no individual diagnosis predominating. Analysis of the delta-betas did not identify any observation exerting undue influence on the parameter estimates.

Discussion

Our study identified travel in the previous 24 h as an increased risk for SCOD. As for all the variables, the recent time period of interest for travel was 4 weeks prior to the onset of colic (or the interview for controls). In this way, any travel episodes occurring as a result of the colic episode were not included in this variable. Therefore, the high-risk period for SCOD appeared to be for the following 24 h after transport. The mechanism for travel to be associated with SCOD is not clear. The act of transportation itself may be important or it may be representative of a large number of other management changes happening simultaneously, such as a change in premises or period of physical constraint combined with possible feed and water deprivation.

Crib-biting/windsucking was a strongly associated risk factor for SCOD in our study. Although White (1997) has associated crib-biting/windsucking with an increased risk of colic, later studies have not identified risk factors for colic associated with the horse's temperament or vices. Although many of the cases were observed to exhibit this vice while hospitalised for diagnosis and treatment, as for all the variables, only carer-reported vices were considered for analysis. Carers preconceptions of any association between this vice and colic may have resulted in reporting bias for this variable. However, the authors feel that this was minimised by the study design and subsequent analysis of hospital records confirmed the difference in prevalence of this vice between colic cases and other hospitalised horses. McGreevy (1996) recognises an association between wind-sucking and colic, although previous work suggests it is not a result of the direct ingestion of air into the stomach (McGreevy *et al.* 1995). Later work by the same authors showed a prolongation of intestinal transit times in crib-biting horses (McGreevy *et al*. 2001) and this may provide a mechanism for the increased risk of SCOD associated with this vice.

In our study, a recent change in exercise was significantly associated with an increased risk of SCOD. Cohen *et al.* (1999) also found an association between colic and a recent change in exercise activity. Further analysis of the change in exercise and SCOD showed that it could be specified as a decrease in frequency or duration, or any change in intensity. Love *et al.* (1994) also found that a reduction in level of exercise was associated with the onset of colic caused by a pelvic flexure impaction. The present study also suggests that the high-risk period is approximately one week following the change in exercise as the risk appears to decline after this period. Possible mechanisms linking exercise-related events and colic in the horse are unclear. Some authors have suggested a correlation with feeding (Reeves *et al.* 1996) or housing practices (Cohen *et al.* 1999), although our observed relationship remains having allowed for these potential confounders. In human medicine, there is thought to be an association between exercise and large intestinal motility (E. Lloyd-Davies, personal communication); and in the horse, any reduction in large intestinal motility, as a result of a change in exercise, could predispose to the development of SCOD.

We identified an increasing number of hours per day spent in a stable as a significant risk factor for SCOD, with stabling for 24 h per day associated with the greatest risk (OR in model 1 = $1.16^{24} = 35.2$). It is closely and inversely correlated with an increasing number of hours per day spent at pasture, with the former being a risk factor and the latter protective for SCOD. This increased risk associated with stabling has not been previously reported in the results of multivariable analysis from earlier studies. It has been previously recorded in 2 studies from Texas (Cohen *et al.* 1999; Hudson *et al.* 2001), but only from their univariable analysis at a 10% significance level. In contrast, Reeves *et al.* (1996) reported that, compared to horses stabled indoors, those with pasture access were at an increased risk of colic. In the univariable analysis, our study identified an additional increased risk of SCOD associated with a change of housing and also identifies a high-risk period for the 14 days following the housing change. This is similar to that reported by Cohen *et al.* (1999). Further analysis of the housing change shows that increasing the hours stabled and decreasing the hours at pasture were highly correlated and both were associated with an increased risk of SCOD similar to the stabling effect reported above. Types of bedding have not previously been identified as risk factors for colic. Our study has also identified the use of paper bedding or rubber mats as having a decreased risk of SCOD compared to the use of straw/hemp bedding; however, this was confounded by other variables in the final model. Our findings of an increased risk associated with stabling and in the univariable analysis a decreased risk associated with access to grass at pasture are closely correlated and may represent different measures of the same effect. In any event, the movement of a horse away from its natural grazing environment appears to be strongly associated with an increased risk of SCOD.

Our study shows an increasing risk of SCOD with an increasing time duration since the horse last received routine dental care. Dental care has not previously been associated with colic (Cohen *et al.* 1995; Reeves *et al.* 1996; Cohen 2002). The precise mechanism for this association is unclear, but reduced mastication of feed with subsequent ingestion of longer length dietary fibre may be important.

In the univariable analysis, we found an increased risk of SCOD with anthelmintic administration in the previous 7 days. This is similar to Morris *et al.* (1992) who have previously reported that horses with a large colon displacement were significantly more likely to have received an anthelmintic in the previous 30 days. In addition Cohen *et al.* (1999) have recorded an increased risk of colic with anthelmintic administration in the previous 7 days. It is possible that this represents a specific localised effect associated with anthelmintic administration and justifies further investigation. Several other studies have shown a protective effect on colic of a regular anthelmintic or parasite control programme (Uhlinger 1990; Reeves *et al.* 1996; Cohen *et al.* 1999) and it is probable that the protective effects on SCOD of moxidectin and/or ivermectin administration in the previous 12 months represents a similar finding.

The increased risk of colic and increasing concentrate feeding found in the univariable analysis in our study has been reported previously (Tinker *et al.* 1997). A recent change in concentrate feeding associated with an increased risk of SCOD has also been previously associated with an increased risk of colic (Tinker *et al.* 1997; Cohen *et al.* 1999). Further analysis showed that a change in concentrate feeding frequency, amount or source/origin were each associated with an increased risk of SCOD, although these changes were all closely correlated with each other. None of the feeding variables remained in the final model although there are close correlations between the recent change in regular exercise programme and several of the feeding changes. For a change in concentrate feeding the high risk period appeared to be the following 14 days with an additional increased risk in the immediate 7 days following a change.

In the univariable analysis a previous history of lameness or orthopaedic related problems was associated with an increased risk of SCOD and this was most marked if it occurred in the previous 4 weeks. As expected, this factor was closely correlated with other management changes (increased time stabled, reduction in exercise, feeding changes) which may represent sequences of events on the causal pathway. Similar to other studies of colic (Ducharme *et al.* 1983; Pascoe *et al.* 1983; Moore and Dreesen 1993; Cohen *et al.* 1995, 1999; Reeves *et al.* 1996; Tinker *et al.* 1997), we found an increased risk of SCOD associated with a history of a previous colic episode. However, unlike some other studies where colic was also associated with a history of previous abdominal surgery (Moore and Dreesen 1993; Cohen *et al.* 1995, 1999; Cohen and Peloso 1996), no association was found between previous abdominal surgery for colic and SCOD, but this may represent the small number of horses in our study (only 5 from 228 horses had a history of previous abdominal surgery for colic), or the relationship between adhesions following abdominal surgery and small intestinal (rather than large intestinal) dysfunction (Fubini 2002).

The case selection in this study was more specific than previously used. Other studies have taken cases from horses showing colic due to any cause (Cohen *et al.* 1995, 1999; Cohen and Peloso 1996; Reeves *et al.* 1996; Tinker *et al.* 1997). Given the wide range of causes of colic and their pathogenesis, it is probable that these studies could miss some important disease specific findings (Reeves *et al.* 1996; Cohen *et al.* 1999) and it has been suggested that future studies should look at specific colic diseases or broad disease groups (Reeves *et al.* 1996). The SCOD definition was devised to create a colic group with anatomical and physiological similarities, which could be distinguished clinically and create sufficient cases within the study time period. It is similar to the definition used by Moore and Dreesen (1993), although they looked at cases of colon distension with a strangulation and their study population was restricted to Thoroughbred mares on 14 studfarms in Kentucky. Even within this case definition it is possible that there are confounding effects between the different diagnoses and more specific diagnoses could be considered for future investigation.

The study design meant that the controls were randomly selected from a similar at risk population to the cases (i.e. horses referred to the veterinary school if they developed SCOD). This is unlike other case control studies which have used hospital and veterinary practice-based controls selected from the same equine population but restricted by the necessity to have another illness or requirement resulting in their presentation to a veterinary surgeon (Cohen *et al.* 1995, 1999; Cohen and Peloso 1996; Reeves *et al.* 1996; Hudson *et al.* 2001). Such studies using hospital-based controls, with other illnesses, are prone to bias (Schlesselman and Stolley 1982). The controls were matched with the cases only by time of questionnaire completion. This meant that no information on the seasonality of SCOD could be derived from this study.

The high sensitivity and specificity of the final models may, in part, be due to the restricted outcome measure used in this study compared to previous studies, which included all types of colic. It has previously been suggested that the outcome measure of all colic types may not be appropriate for epidemiological investigation of risk factors as it is probable that there are important disease-specific findings which will be missed (Reeves *et al.* 1996; Cohen *et al.* 1999). For the present study, a restricted group of colic causes (SCOD) was selected deliberately. While there may be pitfalls in this case selection, it was chosen to allow enough cases to be enrolled in the study timeframe and in the belief that there were common anatomical, physiological and aetiological factors amongst the group. Analysis of the sub-groups of individual diagnoses, which together made up the SCOD group, confirmed this view, with each of the individual diagnoses fitting the final models. The variables of a history of residing on the current establishment for less than 6 months, a previous colic episode and the fewer times per year the teeth are checked/treated appeared in only one of the final models. When forced into the other final model there was evidence of confounding, with these variables being highly correlated with other variables of interest and resulting in large changes to the odds ratios for these variables.

The variables of a history of a previous colic episode (Cohen *et al.* 1995, 1999; Reeves *et al.* 1996; Tinker *et al.* 1997) and a recent change in exercise (Cohen *et al.* 1995) have been identified previously in multivariable analysis as risk factors for colic, as well as now specifically for SCOD. Regular parasite control with anthelmintics has also been identified as being associated with colic (Kaneene *et al.* 1997; Cohen *et al.* 1999). Our finding of a protective effect on SCOD of ivermectin or moxidectin administration in the previous 12 months is similar to the protective effect reported by Cohen *et al.* (1999), although Kaneene *et al.* (1997) found increasing 'deworming' frequency to be associated with an increased risk of colic. Crib-biting or windsucking, the number of hours per day stabled, a history of transport, residing on the current premises for less than 6 months and the annual frequency of dental examination/treatment have not been identified previously in multivariable models as risk factors for colic. However, the design of this study does not allow the establishment of a causal association between these risk factors and SCOD.

From the final multivariable models, 6 of the variables relate directly to management practices and all of these are potentially alterable. It is hoped, therefore, that knowledge of the results of this study may be helpful in reducing the incidence of colic episodes due to SCOD. It is interesting to note that, almost 100 years ago, in his treatise on the common colics of the horse, Caulton Reeks (1909) identified "far and away the most common cause of equine colics is the one that may be best described by the single word 'domestication'", a comment that would appear equally true for SCOD.

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