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Factors influencing the development of stereotypic and redirected behaviours in young horses: findings of a four year prospective epidemiological study

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Summary

Stereotypies are invariant and repetitive behaviour patterns that seemingly have no function, which tend to develop in captive animals faced with insoluble problems and may be indicative of reduced welfare. A 4 year prospective study of the factors influencing the development of stereotypic and redirected behaviours (abnormal behaviour) in a population of 225 young Thoroughbred and part-Thoroughbred horses was conducted between 1995 and 1999. Abnormal behaviour affected 34.7% of the population. Multivariable analysis showed that foals of low- or middle-ranking mares were less likely to develop abnormal behaviour than foals of dominant mares (rate ratio (RR) 0.23, P<0.01; RR 0.48, P<0.01, respectively). Weaning by confinement in a stable or barn was associated with an increased rate of development of abnormal behaviour, compared with paddock-weaning (RR 2.19, P<0.05), and housing in barns, rather than at grass after weaning, was associated with a further increase (RR 2.54, P<0.01). Specific stereotypic and redirected behaviours were then considered as separate outcomes. Crib-biting was initiated by 10.5% of horses at median age 20 weeks, weaving by 4.6% of horses at median age 60 weeks, box-walking by 2.3% of horses at median age 64 weeks and wood-chewing by 30.3% of horses at median age 30 weeks. Wood-chewing developed at a lower rate in horses born to subordinate or mid-ranking mares than in horses born to dominant mares (RR 0.29, P<0.01; RR 0.41, P<0.01, respectively), and at a higher rate in horses kept in barns or stables rather than at grass after weaning (RR 4.49, P<0.001; RR 1.46, P<0.001, respectively). Feeding concentrates after weaning was associated with a 4-fold increase in the rate of development of crib-biting (RR 4.12, P = 0.02). The results of this study support the idea that simple changes in feeding, housing and weaning practices could substantially lower the incidence of abnormal behaviour in young horses.

Introduction

Stereotypies are invariant and repetitive behaviour patterns that seemingly have no function. They develop in captive animals faced with insoluble problems (Mason 1991) and may be indicative of reduced welfare. In horses, behaviours such as crib-biting, weaving and box-walking are classed as stereotypies. Wood-chewing is also of interest as, although not sufficiently invariant to be classed as a stereotypy, it may precede or be associated with the development of crib-biting (Nicol 1999). There is considerable debate about the specific causes and functional significance of different stereotypic behaviour patterns in the horse; and epidemiological analysis has been used to good effect in recent years to examine patterns of distribution. Differences in the prevalence of equine stereotypy associated with breed, sporting use or gender have been demonstrated in surveys of owners and managers (Canali and Borroni 1994; McGreevy *et al*. 1995a; Luescher *et al.* 1998). Within-population surveys of genetically similar Thoroughbred horses have also been able to elucidate influential management factors. Positive associations have been detected between stereotypy prevalence and low forage ration, stable designs that limit the degree of social contact between horses, the use of nonstraw bedding and the provision of concentrate feed (McGreevy *et al.* 1995b; Redbo *et al.* 1998).

Although such surveys provide important information, they are essentially retrospective and cannot provide substantive data to support cause and effect relationships. Events in the lives of the animals preceding the survey have not been determined and findings are therefore based on a snapshot picture in time. Cause and effect relationships can be determined more accurately in prospective studies, where individual horses are studied over time and the exposure of each animal to different events can be recorded in sequence and related to the time of onset of any behavioural problem. A further difficulty is that cross-sectional surveys have focused on mature horse populations. Studies of other species have demonstrated that young animals are influenced by their environment to a greater extent than older animals, and are particularly susceptible to developing stereotypic behaviour in captive conditions (Cooper and Nicol 1996; Powell *et al.* 2000). In mature animals, stereotypic behaviour can become a habit, performed in contexts that are increasingly distant from the original causal situation (Cooper and Nicol 1991; Mason 1993). Conclusions about causation based on the management of mature populations may, therefore, be of limited value.

Another reason to study young animals is that the practice of early weaning is a major cause of stereotypic behaviour in many species, including rodents (Würbel and Stauffacher 1997). Horses

TABLE 1: The 'survival' pattern with respect to the development of abnormal behaviour in a population of 225 young horses

Interval since birth (months)	Number normal	Abnormal behaviour during interval*	Oral behaviour: crib-biting and wood-chewing	Locomotor stereotypies	Loss during interval†	Number at risk‡	Risk of abnormal behaviour developing during interval	Cumulative probability of not developing abnormal behaviour
3	151	12	12	1	3	149.5	0.0802	0.9198
6	182	17	15	5	5	179.5	0.0947	0.8327
9	176	28	28	0	25	163.5	0.1712	0.6901
12	125	5	5	0	17	116.5	0.0429	0.6605
15	124	2	1	2	5	122.5	0.0164	0.6497
18	108	0	0	0	4	106	0.0163	0.6391
21	104	1	1	0	3	102.5	0.0098	0.6328
24	87	3	2	2	14	80	0.0375	0.6091
27	83	3	2	1	1	82.5	0.0363	0.5870
30	81	3	3	1	0	81	0.037	0.5652
>30	78	4	3	3	5	75.5	0.052	0.5358

*Abnormal behaviour comprised oral behaviour and locomotor behaviour. Some horses developed both oral and locomotor abnormalities. †Net loss during interval, i.e. number of horses entering the study minus the number leaving the study (due to death, or because they were enrolled in 1998 as foals and were less than 30 months of age when the study ended, or lost to follow-up). ‡Number of normal horses - 1/2(number lost during interval). This assumes losses occurred evenly throughout the 3 month interval.

are commonly weaned at age 4–6 months (Apter and Householder 1996) using a variety of methods. Foals weaned abruptly show greater signs of stress than foals weaned more gradually (McCall *et al.* 1985, 1987; Malinowski *et al.* 1990; Hoffman *et al.* 1995; Apter and Householder 1996) but it is not currently known whether weaning method affects the development of equine stereotypies.

The aim of this study was to focus on factors influencing the development of abnormal behaviour in young Thoroughbred and part-Thoroughbred horses. A 4 year prospective study of 225 young horses was conducted to identify the management factors responsible for the onset of abnormal behaviour in individual animals.

Materials and methods

Study design

Two hundred and twenty-five Thoroughbred and part-Thoroughbred horses, born on 5 studfarms in Gloucestershire and Worcestershire, England (154) or bred by private owners (71), were entered into the study between 1995 and 1998. Individual horses entered or left the study at different times; therefore, cohorts were dynamic. Altogether, 35 horses were followed for 3–4 years, 63 horses for 2–3 years, 68 horses for 1–2 years, and 59 horses for less than 1 year. The majority of horses were recruited as foals but some horses entered the study at a later stage and contributed information from then on (Table 1). Each foal was observed directly during the preweaning period, at weaning and 2–4 months after weaning. Regular contact was maintained after weaning. The outcome of interest was the time of onset of abnormal behaviour, defined as the stereotypic behaviours of crib-biting (the horse grasps a fixed object with its incisor teeth, contracts the neck muscles and draws air into the cranial oesophagus), weaving (the horse sways the head and sometimes the neck and forequarters laterally) and box-walking (the horse performs rapid 'escape' walking), and the redirected behaviour of wood-chewing (the horse bites, chews and may ingest wood from any available structure in its environment).

The number of horses entered into the study was based on our previous work (McGreevy *et al.* 1995b) which suggested that, if approximately 10% of horses develop stereotypic behaviour over the first 3 or 4 years of their lives, this would give a constant rate of approximately 0.035 incident cases per horse year. A minimum rate ratio of 3.0 (the ratio of incidence of cases in exposed animals to the incidence of cases in unexposed animals) was considered worth detecting in the present project and, therefore, a minimum of 400 horse years of study were needed to give 80% power to detect such a ratio with 95% confidence. The number of horse years used in the current analysis equalled 403.

Behavioural observations: Data recording was carried out using focal sampling using a Psion organiser (Observer 3 programme) or by hand, using stopwatches. A team of 6 trained observers carried out all sampling. Prior to data collection, intra-observer reliability was assessed by repeated observation of video sequences of mare and foal behaviour. Interobserver reliability was assessed informally by discussion of discrepancy and iteration until discrepancy was minimised. Mares were observed for 10 h over a spread of 2 weeks to ascertain their social rank, defined as dominant, middle-ranking or low-ranking, based on the ratio of number of threats given and received by each mare. Foals were observed for 10 h (1 h every 2 weeks) preweaning in order to detect the onset of any abnormal behaviour. Foals were also observed for 3 h at weaning, immediately following separation of the foal and dam. Postweaning observations took place between 2 and 4 months following weaning, foals were observed for a total of 10 h. As foals were housed either individually or in small groups, they were easy to observe and the quality of data obtained was equally high across different housing systems.

Postweaning information: Owners were sent guidelines and definitions of abnormal behaviours, and instructed to contact us as soon as any study horse began to perform an abnormal behaviour. A randomly-selected 60% of horses were visited every 6 months, and the owners of the remainder were contacted by telephone every 6 months. If a horse developed stereotypic behaviour a final

TABLE 2: Multivariable relationships between management factors and the development of any abnormal behaviour

Variable	n	Rate ratio	95% CI	Wald test P value	LRS Pvalue
Sex of horse					
Female	101	1.00			
Male	124	1.16	0.72–1.85	0.52	0.52
Breed					
Non-Thoroughbred	99	1.00			
Thoroughbred	126	2.04	0.89–4.70	0.09	0.09
Stud					
Stud 1	39	1.00			
Stud 2	25	2.81	0.86–9.21	0.09	
Stud 3	5	1.92	0.50–7.39	0.33	
Stud 4	60	0.5	0.15–1.66	0.26	
Stud 5	25	2.23	0.57–8.71	0.24	
Stud 6	71	1.09	0.47–2.53	0.82	0.007
Mare rank					
Dominant	53	1.00			
Mid-ranking	148	0.48	0.28–0.81	0.006	
Low-ranking	24	0.23	0.07–0.83	0.02	0.009
Weaning method					
Paddock-weaned	107	1.00			
Barn-weaned	79	2.19	0.98–5.98	0.05	
Box-weaned	27	2.18	1.09–5.33	0.02	
Unweaned	12	0.15	0.02–1.15	0.07	0.009
Postweaning housing					
At grass	74	1.00			
Barned	83	2.54	1.26–5.13	0.009	
Stabled	64	1.03	0.38–2.81	0.93	<0.001

confirmatory visit was made, although wood-chewing horses were followed to ascertain whether they subsequently developed a stereotypy. In addition, questionnaires and covering letters were sent to all owners or trainers in January 1996, January 1997, January 1998 and January 1999. The questionnaires asked for details of management (including housing and feeding practices) and the health and behaviour of individual horses. Owners were required to confirm the time of onset of any abnormal behaviour observed by us or previously reported to the nearest week. Owners who reported abnormal behaviour for the first time in the questionnaires were immediately telephoned to verify the time of onset. Owners who did not return the questionnaires were telephoned and asked the questions about management and behaviour directly.

Data analysis: The outcome variable was the time to development of abnormal behaviour and the explanatory variables were recorded about individual horses and their management. Individual horse variables were sex, breed, age at weaning, hierarchical rank of dam and postweaning health. Management variables were weaning method, type of postweaning housing used, type of postweaning forage fed and whether postweaning diet included concentrate feed. Weaning techniques encountered in this study were box-weaning (abrupt weaning with complete separation and isolation from conspecifics, usually involving a substantial period of confinement in the stable); barn-weaning (abrupt weaning carried out with small groups of foals kept together in a loose-housed situation, n = 6–20); paddock-weaning (abrupt weaning, usually with groups of weanlings being kept together in a field situation, n = 2–20. In 50% of cases, one or 2 'nanny' mares were left with groups); and natural weaning (gradual weaning of foals by mares).

The data were analysed using event-time analysis. Kaplan-Meier plots were used to display graphically the time to development of abnormal behaviour. The cumulative probability of not developing abnormal behaviour was plotted against time from birth for each variable where more than 2% of horses were exposed to that variable. Cox proportional hazards models were used to examine bivariable relationships between explanatory variables and time to development of abnormal behaviour after adjusting for the confounding effects of stud by including this variable as a fixed effect in the model. Multivariable models were then constructed to adjust for confounding by other key variables using forward step-wise procedures and by examining the effects of including different variables on parameter estimates. All variables were offered to the stepwise model. Breed and sex were forced into the model, but the remaining variables were retained only if their P-value was <0.05. The proportionality assumption was tested by examining the Schoenfeld residuals (Grambsch and Therneau 1994). The software Egret and S-Plus 2000 was used for analyses.

Results

Information acquisition

The owners of 46% of the horses that developed abnormal behaviour contacted us spontaneously to report the date of onset. These owners also completed the annual questionnaires, contributing to the overall questionnaire return rates of 87%

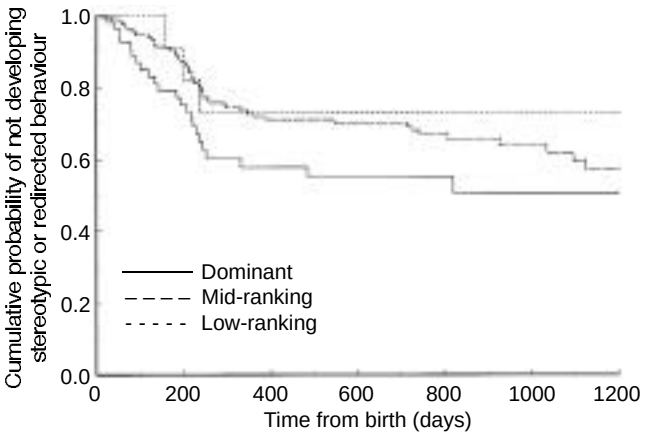

Fig 1: Time to development of abnormal behaviour in foals of dominant, mid-ranking and low-ranking mares.

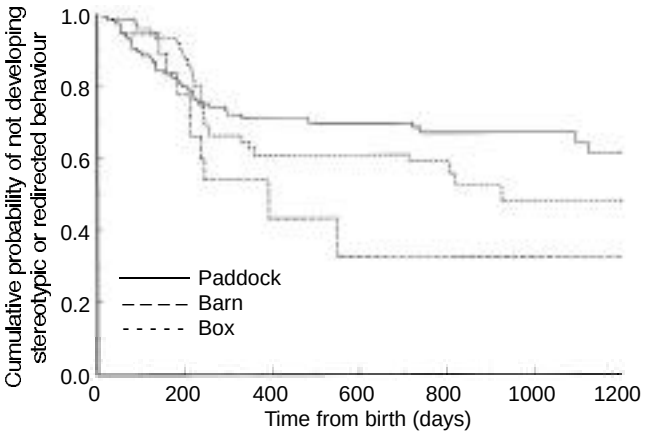

Fig 2: Time to development of abnormal behaviour in foals weaned by different techniques.

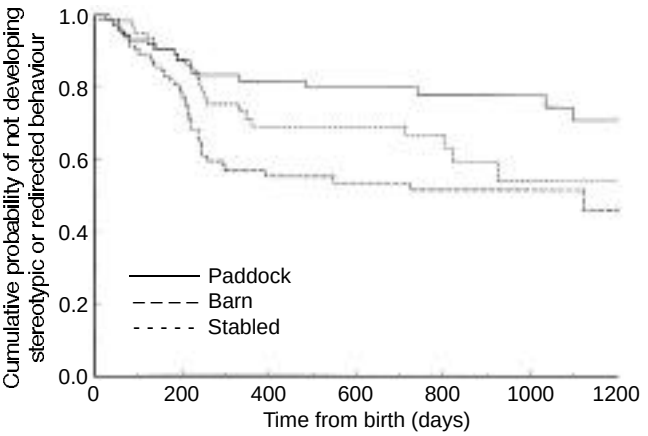

Fig 3: Time to development of abnormal behaviour in foals kept in different environments postweaning.

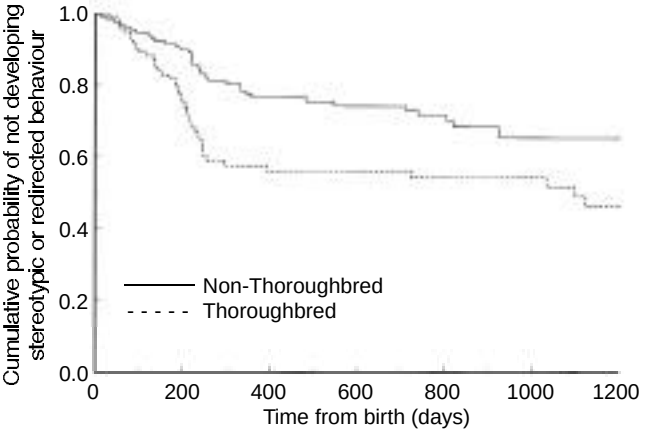

Fig 4: Time to development of abnormal behaviour in Thoroughbred and non-Thoroughbred foals.

(1996), 77% (1997), 69% (1998) and 66% (1999). The abnormal behaviour of a further 12.8% of horses was first detected from a returned questionnaire. The abnormal behaviour of the remaining 41% of horses was detected directly during a behavioural observation. Telephone interviews were conducted to gain the required information on the management and behaviour of horses belonging to nonrespondents, resulting in full information for all but 7 of the 225 study horses. These 7 horses were lost to follow-up due to being sold on several times or exported overseas, but they contributed information up to the point of their departure from the study. Four horses died before weaning.

Description of management

The majority of horses, 70%, were weaned between ages 4 and 6 months, although 12% were weaned at less than 4 months, 11% at 6–8 months and 2% were more than 8 months at weaning. Five percent of horses were not formally weaned or died prior to weaning. The numbers of horses exposed to each management variable are shown in Tables 2 and 3.

Development of stereotypic and redirected behaviour

Abnormal behaviour affected 34.67% of the study population. Crib-biting was initiated by 10.5% of young horses at median age 20 weeks, weaving by 4.6% at median age 60 weeks, box-walking by 2.3% at median age 64 weeks and wood-chewing by 30.3% of young horses at median age 30 weeks. Animals were deemed 'normal' for as long as they remained in the study population without developing abnormal behaviour. The estimated 'abnormality'rates and trimonthly 'abnormality'risks for each age category are shown in Table 1. This shows that the onset of abnormal behaviour was particularly predominant between birth and age 9 months.

Risk factors for abnormal behaviour

Bivariable analysis: After adjusting for the fixed effects of studfarm, foals of middle- and low-ranking dams had a lower risk of developing behavioural problems than those of dominant mares ($P<0.01$; Fig 1). There was, however, no significant bivariable relationship between breed, sex, weaning age, mare type or postweaning forage or postweaning feed ($P>0.27$ in all cases).

Horses which were box-weaned were associated with a significantly greater risk of developing behavioural problems than horses weaned by any other technique; for example, when compared with paddock-weaning the risk increased more than 2-fold ($P = 0.015$; Fig 2). Horses which were barned or stabled after weaning were at significantly greater risk than those which were pastured ($P<0.01$; Fig 3).

TABLE 3 : Multivariable relationships between management factors and wood-chewing

Variable	n	Rate ratio	95% CI	Wald test P value	LRS P value
Sex of horse					
Female	101	1.00			
Male	124	1.05	0.63–1.77	0.82	0.82
Breed					
Non-Thoroughbred	99	1.00			
Thoroughbred	126	1.54	0.55–4.32	0.40	0.40
Stud					
Stud 1	39	1.00			
Stud 2	25	5.09	1.02–25.24	0.04	
Stud 3	5	8.29	1.73–39.65	0.01	
Stud 4	60	1.19	0.22–6.17	0.83	
Stud 5	25	7.01	1.17–42.12	0.03	
Stud 6	71	1.08	0.36–3.21	0.89	0.001
Mare rank					
Dominant	53	1.00			
Mid-ranking	148	0.41	0.23–0.73	0.002	
Low-ranking	24	0.29	0.08–1.04	0.06	0.009
Postweaning forage					
Hay	184	1.00			
Other	37	2.72	0.99–7.51	0.05	0.05
Postweaning feed					
No hard feed	140	1.00			
Hard feed	81	0.38	0.16–0.89	0.02	0.023
Postweaning housing					
At grass	74	1.00			
Barned	83	4.49	1.99–10.09	<0.001	
Stabled	64	1.46	0.57–3.76	0.42	<0.001

Multivariable analysis: After adjusting for the confounding effects of other key variables, foals of middle- and low-ranking dams had a lower risk of developing behavioural problems than those of dominant mares. Thoroughbred foals appeared to have a higher risk of developing abnormal behaviour compared to non-Thoroughbreds, but this was of borderline significance (P = 0.09) (Table 2; Fig 4).

Horses which were box- or barn-weaned were at significantly greater risk of developing behavioural problems than horses weaned by other techniques. When compared with paddock weaning, the risk increased more than 2-fold for box-weaning and similarly for barn-weaning. Horses which were housed in barns postweaning were at significantly greater risk than those which were pastured (Table 2). The influence of housing beyond age 1 year was more difficult to assess, as individual housing histories became complex, and was not formally entered into the model. However, full-time stabling at 24 months was recorded for 40% of the study population overall, but for all 10 horses that developed abnormal behaviour after 24 months.

Risk factors for individual behaviours

Wood-chewing: In an initial bivariable analysis that adjusted for the fixed effects of studfarm, foals of middle- and low-ranking mares were at lower risk of developing wood-chewing than foals of dominant mares (P= 0.05). Weaned horses which were stabled or barned were at significantly greater risk of wood-chewing than those which were pastured (P<0.05). There were no other significant bivariable relationships (P>0.18 in all cases). Multivariable analysis revealed significant associations between stud, type of postweaning housing, type of postweaning forage and mare rank in the development of wood-chewing. Provision of concentrate feed postweaning was associated with a reduced risk of wood-chewing (Table 3).

Crib-biting: After adjusting for the confounding effects of studfarm, the only management level variable significantly associated with crib-biting was postweaning feed, with foals receiving concentrate feed at 4 times greater risk of developing crib-biting than those that did not (Table 4). Of the foals which developed this behaviour, 74% had shown wood-chewing prior to crib-biting. As only small sample sizes were available for analysis, multivariable analysis was not carried out.

Weaving and box-walking: No statistically significant associations were found in the univariable and bivariable analyses. This may be explained by the relatively low numbers of horses that developed locomotory stereotypies; hence only small sample sizes were available for analysis. For this reason, multivariable analysis was not carried out.

Examination of the Schoenfeld residual plots did not reveal significant departures from the assumption of proportionality with the exception of barn weaning in the model of any abnormal behaviour and forage feeding in the model of wood chewing. Both showed evidence of an increase in the risk ratio over time.

TABLE 4: The bivariable relationship between management factors and crib-biting in young horses (adjusted for confounding effects of stud entered as a fixed effect)

Variable	n	Rate ratio	95% CI	Wald test P value	LRS P value
Sex of horse					
Female	101	1.00			
Male	124	0.95	0.42–2.16	0.90	0.90
Breed					
Non-Thoroughbred	99	1.00			
Thoroughbred	126	0.72	0.16–3.14	0.68	0.68
Mare rank					
Dominant	53	1.00			
Mid/low rank combined	172	0.47	0.20–1.11	0.08	0.08
Postweaning forage					
Hay	184	1.00			
Other	37	2.45	0.29–21.03	0.41	0.41
Postweaning feed					
No hard feed	140	1.00			
Hard feed	81	4.12	1.17–14.49	0.02	0.02
Postweaning health					
Good	186	1.00			
Poor	35	2.19	0.84–5.67	0.11	0.11
Postweaning housing					
At grass	74	1.00			
Barned	83	1.27	0.45–3.58	0.65	
Stabled	64	1.52	0.53–4.41	0.43	0.73

Discussion

This first prospective study of the development of abnormal behaviour revealed a number of strongly significant management risk factors. Behavioural problems were significantly more common in Thoroughbreds, foals of dominant mares, horses that had been produced on certain studfarms, horses that had been box- or barn-weaned and horses that had been housed after weaning, as opposed to pastured. Horses that received concentrate feed after weaning had a significantly greater risk of developing crib-biting than those that did not, and horses fed on hay replacers (haylage or silage) as opposed to hay after weaning had a significantly greater risk of developing wood-chewing. The rate of development of stereotypic and redirected behaviour was greatest during the first 9 months of life. Time-related patterns for the development of oral behaviours differered notably from those of locomotory behaviours. The interpretation and implications of each of these findings is discussed below.

The strong effect of weaning is of considerable importance. Weaning is a stressful time for the juvenile and abrupt weaning has been implicated as a source of emotional anxiety and physiological changes in many domestic species (Wood-Gush *et al.* 1975; McCall *et al.* 1985, 1987; Apter and Householder 1996; Day and Webster 1999). In horses, many aspects of management alter at weaning time; the mare-foal bond is severed and sucking is no longer possible, feeding practices are altered, the amount of human contact is often increased, and housing and new social groupings are frequently introduced. On the studfarms used in this study, weaning was usually carried out between ages 3 and 8 months, with Thoroughbred breeders favouring early weanings. Age at weaning was not, however, significantly associated with the development of abnormal behaviour; the weaning technique used appeared to be far more important.

Traditional box- and barn-weaning methods are total and abrupt, involving sudden and permanent separation of the mare and foal. Weaned foals frequently attempt to redirect sucking behaviour towards the genital regions of conspecifics. The frustrated motivation to suck postweaning may be one cause of crib-biting and wood-chewing in some individuals. Weaned foals may be kept in complete isolation or housed with conspecifics of similar age, but the fact that the risk of developing abnormal behaviour was equally high in barn-weaned as box-weaned horses suggests that the presence of companions was not sufficient to reduce the impact of weaning. The paddock-weaned horses had a lower risk, although they were also weaned abruptly, albeit sequentially in some cases. The presence of other calm, grazing horses may have reduced the stress of weaning for these foals. Recent studies suggest that foals weaned by gradual separation may be even less stressed (Hoffman *et al.* 1995; Apter and Householder 1996) but we were unable to evaluate the effects of such techniques as they are rarely used in the UK.

Postweaning housing was another management factor that was strongly associated with the development of abnormal behaviour. Barned weanlings were at greater risk of developing abnormal behaviour than paddock-kept weanlings. Social problems may arise in barned situations due to the enforcement of new social groupings within a restricted environment. During direct observations at weaning, it was noted that high levels of aggression between individuals and bullying of new foals joining established bands was common.

Young horses that received concentrates after weaning were 4 times more likely to develop crib-biting than those that did not.

This relationship was strongly influenced by the group of private owners (Stud 6) in which 7/30 horses fed hard feed developed crib-biting compared to 0/39 that were not fed hard feed. Many foals receive concentrate feed from birth, often by accessing their mother's feed; others are given concentrate diets just prior to weaning to encourage good growth. A relationship may exist between gut acidity and incidence of oral activites such as crib-biting, grasping and wind-sucking (Johnson *et al.* 1998). Nicol (1998) suggested that crib-biting may increase the flow of alkaline saliva and reduce gastric acidity associated with feeding concentrates (Nadeau *et al.* 2000). McGreevy and Nicol (1998a,b) also suggested that normal gut motility and transit times in crib-biting horses may depend on physical flushing by saliva associated with their crib-biting behaviour. The origin of crib-biting may, therefore, be associated with specific dietary problems in the horse.

It was unexpected that the provision of concentrate feed after weaning in this study was associated with a reduction in the risk of wood-chewing, as wood-chewing is thought to share some causal factors with crib-biting (Nicol 1998). There was a high degree of correlation between concentrate and hay feeding (horses that received concentrate feed also received hay as forage (80 horses) rather than a hay replacer such as haylage (one horse) and the relationship between concentrate feeding and wood chewing was observed only in the hay-feeding group (although the interaction was not statistically significant). High energy haylage generally replaced hay and concentrate feed (36 horses) and was associated with the development of wood-chewing. Haylage was often fed in restricted quantities, which could result in the redirection of oral behaviour due to increased motivation to forage because of decreased gut-fill (Nicol 1998) or other feedback mechanisms (Johnson *et al.* 1998). Hay replacers may also exert different physiological effects on the digestive system of young horses. Krzak *et al.* (1991) reported that wood-chewing increased when the stomachs of horses were empty. Willard *et al.* (1977) and Johnson *et al.* (1998) reported that horses fed on low forage diets spent significantly more time chewing wood than horses fed hay. Further, Johnson *et al.* (1998) found that abnormal biting of the stable and wood-chewing were reduced in horses fed a predominantly concentrate diet that was supplemented with virginiamycin, a substance which acts to suppress lactic acid production in the hindgut and therefore reduces hindgut pH.

Foals of dominant mares had a higher incidence of behavioural problems than foals of middle- or low-ranking dams. This may reflect influence of mare behaviour towards foals prior to weaning, genetic factors determining behaviour, or relate to the nature of the mare-foal bond and effects of severence at weaning (A.J. Waters and C.J. Nicol, unpublished data).

Approximately 27% of the Thoroughbreds in this study developed abnormal behaviour. Thoroughbreds are generally managed for rapid growth and development, to enable training early in life and racing at age 2 or 3 years. Factors characteristic of such management regimes may contribute to this high incidence since, once we included management factors in a multivariable analysis, an initially apparent 'breed'effect was no longer significant. Confounding effects of management on Thoroughbred behaviour were also noted by Redbo *et al.* (1998).

The incidence rates reported in this study are considerably higher than the prevalence figures (between 7% and 15%) for mature Thoroughbred horses reported by McGreevy *et al.* (1995a), Luescher *et al.* (1998) and Redbo *et al.* (1998); but comparable to those given by Canali and Borroni (1994) for Italian Thoroughbreds of age less than 2 years (23.8%). The percentage of horses in this study that initiated locomotor stereotypies is within the range reported by other authors (e.g. Luescher *et al.* 1998; Redbo *et al.* 1998), whereas the percentages of horses performing crib-biting and wood-chewing clearly exceed the maximum prevalences reported in published cross-sectional studies. However, data from cross-sectional studies may underestimate true prevalence due to owner error or reluctance to admit a problem. Alternatively, stereotypic foals may be more likely to be culled, or may suffer from higher natural mortality and therefore not appear in the mature horse population. More optimistically, a proportion of young horses may cease to show oral stereotypies as they age or in response to appropriate management changes, to which they may be more responsive than mature individuals.

The results of this study suggest that weaning method, diet and housing play a critical role in the development of stereotypic and redirected behaviour in young horses. Based upon these findings, the authors recommend that foals are not box- or barn-weaned, are turned out whenever possible, and that hay replacers and concentrates are introduced to the diet of young horses slowly, gradually and in combination with *ad libitum* supplies of hay.

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