



## Review

## Crib-biting behavior in horses: A review

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## ABSTRACT

During the past decade, stereotypic behavior in horses, specifically crib-biting behavior, has received considerable attention in the scientific literature. Epidemiological and experimental studies designed to investigate crib-biting behavior have provided valuable insight into the prevalence, underlying mechanisms, and owner perceptions of the behavior. The findings of these studies have demonstrated how the management of horses can influence their behavior and well being. Management conditions which impede foraging opportunities and social contact, provision of high concentrate diets, and abrupt weaning have been associated with an increased risk of crib-biting. The exact etiology of crib-biting remains to be elucidated, however, results of recent research suggest that dopaminergic pathways may be implicated in the performance of this oral stereotypy. There has also been additional evidence to support the hypothesis that gastrointestinal irritation is involved in crib-biting in horses. Many equine behavior and welfare scientists remain in agreement that management of crib-biting horses should focus on addressing the suspected influential factors prior to attempts at physical prevention of the behavior. The findings of several survey and experimental studies are reviewed, with emphasis on research conducted since the late 1990s, in an effort to provide the reader with a relatively comprehensive look into that which is known about crib-biting behavior in horses. Knowledge deficiencies and areas for future research are identified.

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## 1. Introduction

Stereotypies are defined as repetitive, relatively invariant patterns of behavior with no apparent goal or function (Mason, 1991). Development and continued performance of stereotypic behavior have been linked to sub-optimal

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environments (Ödberg, 1987; Cooper and Albentosa, 2005). Specifically, stereotypic behavior can develop within the following contexts: when an animal is unable to execute a behavior pattern that it is highly motivated to perform, such as feeding behavior; when it cannot escape or avoid a stressful or fearful situation; or when it is kept in confinement or social isolation (Mason, 1991). It has been suggested that stereotypic behavior may serve as a coping mechanism, functioning to reduce stress or to provide the animal with some form of control over its environment (Mason, 1991; Cooper and Albentosa, 2005). The presence of stereotypies has been used as an indicator of poor welfare (Broom, 1983; Mason and Latham, 2004) although whether the welfare is currently poor or has simply been poor in the past is more difficult to determine. Stereotypies have been observed in several species (Mason, 1991) and in captive ungulates, performance of oral stereotypic behavior is common (Bergeron et al., 2006; Mason and Rushen, 2006). Specific examples include object-licking in giraffes, bar-biting and sham chewing in sows, tongue-rolling in cattle, and crib-biting in horses (Mason and Rushen, 2006).

Horses exhibiting crib-biting behavior anchor their top incisor teeth on a fixed object (e.g. fence, stall or building structures), pull backward, contract the neck muscles, and draw air into the cranial esophagus emitting an audible grunt (McGreevy et al., 1995a,b; Dodman et al., 2005). The behavior is not known to occur in feral, free-ranging horses, but is observed in domestic (Haupt and McDonnell, 1993; Mills, 2002) and captive wild horses, e.g. Przewalski horse (Boyd, 1986). Performance of crib-biting behavior has been reported to occupy from 15% (Nicol et al., 2002) up to 65% (Bachmann et al., 2003a) of the daily time budget.

It is widely reported in the literature that crib-biting, and other stereotypic behaviors, are viewed by owners as being problematic and undesirable (Kiley-Worthington, 1983; Haupt and McDonnell, 1993; Nicol, 1999a; Mills, 2002). Crib-biting behavior has been linked to unthriftiness (weight loss and poor condition) in horses. This is thought to be a result of increased energy expenditure and/or a decrease in the amount of time spent eating and grazing during performance of the behavior (Haupt and McDonnell, 1993; McGreevy and Nicol, 1998a). The behavior also has been associated with excessive tooth wear (Owen, 1982; Boyd, 1986), which in severe cases may impair the horse's ability to graze or result in dental disease. Two recent studies have demonstrated an association between epiploic foramen entrapment, a specific form of colic, and crib-biting behavior (Archer et al., 2004, 2008). Despite the latter findings, however, evidence for direct negative consequences of crib-biting behavior on horse health remains largely anecdotal, requiring further empirical investigation and careful documentation.

The precise etiology of crib-biting behavior has yet to be elucidated, and it is likely that the cause is multifactorial. Several studies have been conducted to investigate the potential biological mechanisms underlying crib-biting behavior. For example, crib-biting has been associated with altered neuroendocrine physiology (Gillham et al., 1994; Lebelt et al., 1998; McBride and Hemmings, 2005, 2009) and brain function (Hemmings et al., 2007; Parker et al., 2008b). There is also some evidence to support a role of

gastrointestinal irritation in performance of the behavior (Mills and Macleod, 2002; Nicol et al., 2002; Lillie, 2004). The findings of these studies have greatly enhanced our understanding of the behavior, but in some cases, results have been conflicting or insufficient, and warrant further investigation. Application of survey research methodology to questions about crib-biting behavior has provided some insight into the prevalence of and risk factors associated with the behavior. Specific factors found to be associated with crib-biting behavior include time spent out of the stable, forage and concentrate feeding, breed and sex of horse (McGreevy et al., 1995c; Luescher et al., 1998; Redbo et al., 1998; Bachmann et al., 2003b) and method of weaning (Waters et al., 2002; Parker et al., 2008a). Some of the more recent epidemiological studies have also assessed owner awareness and perceptions regarding crib-biting behavior (McBride and Long, 2001; Albright et al., 2009; Wickens, 2009) in an effort to determine the current level of concern with and knowledge about the behavior within the equine community. A summary of factors influencing the development of crib-biting based on evidence provided in the literature is presented in Table 1.

### 1.1. Aim of the review

Within the past decade, equine scientists have conducted a number of studies designed to examine the etiology of crib-biting behavior. The purpose of this paper is to review the existing literature on crib-biting behavior with special attention directed toward research carried out after the publication of equine stereotypic behavior review articles in the mid- to late-1990s (Winskill et al., 1995; Cooper and Mason, 1998; Nicol, 1999b). Emphasis is placed on our current understanding of the role of neuroendocrine and brain physiology and of gastrointestinal irritation in the performance of the behavior, as well as the contribution of horse characteristics and environmental factors to crib-biting behavior. Recommendations concerning areas needing additional research are made throughout.

## 2. Findings of survey and epidemiological research on crib-biting behavior

The prevalence of crib-biting behavior reported in horses in Europe and Canada is 2.4–8.3% (Vecchiotti and Galanti, 1986; McGreevy et al., 1995c; Luescher et al., 1998). Albright et al. (2009) reported an overall crib-biting prevalence of 4.4% in US horses. Survey studies in the UK and Canada have demonstrated an association between various management practices and stereotypic behavior. For example, a prospective study conducted by Waters et al. (2002) found that young Thoroughbred and part-Thoroughbred horses fed concentrate feed post-weaning were 4 times more likely to develop crib-biting behavior than foals not receiving concentrate. Weaning method also has been associated with the performance of stereotypic behavior including crib-biting. In a recent survey of management practices implemented on breeding farms in Europe, North America, and Australia, natural weaning (mare allowed to wean foal) was associated with a decrease in the chance of foals developing abnormal behav-

**Table 1**  
Summary of factors influencing development of crib-biting in horses.

Physiological mechanisms
Neuroendocrine physiology
Serotonergic system
Serotonin reuptake inhibitors effective in reducing stereotypies
Trend for lower basal serotonin levels in crib-biting compared to non-stereotypic horses
Endogenous opioids
Suggested to facilitate and reinforce stereotypic behavior
Administering opioid antagonists reduces crib-biting
Measurement of plasma $\beta$ -endorphin concentrations in crib-biting horses has produced conflicting results
Hypothalamus–pituitary–adrenal (HPA) axis
Crib-biting hypothesized as an adaptive response to stress
Bouts of crib-biting have been shown to lower plasma cortisol concentration, heart rate, and nociceptive threshold
Measurement of cortisol concentrations in crib-biting horses has produced conflicting results and remains controversial
Dopaminergic system
Dopamine receptor densities have been shown to differ between crib-biting and non-crib-biting horses
Dopamine pathways are important in goal-directed behavior and crib-biting horses have demonstrated difficulties in learning response–outcome contingencies
Gastrointestinal physiology
Crib-biting associated with gastric ulceration in foals
Consumption of an antacid product has been shown to reduce crib-biting behavior in both foals and adult horses
Differences in serum gastrin concentrations and gastric pH have been observed between crib-biting and non-crib-biting horses
Genetics and horse characteristics
Breed predisposition
Thoroughbreds and Warmbloods appear to be at greater risk compared to other breeds
Sex
Male horses, particularly stallions, appear to be at greater risk compared to mares
Management factors associated with increased risk of crib-biting
High concentrate/low forage diets
Housing young horses in individual stalls
Management factors associated with reduced risk of crib-biting
Increased amount of time spent outside of the stable
Allowing horses social contact with others in the same enclosure
Keeping foals exclusively on grass at the time of weaning

ior (Parker et al., 2008a). Post-weaning housing was also associated with the performance of abnormal behavior with decreased risk of abnormal behavior in foals kept exclusively on grass (Parker et al., 2008a). In eventing and dressage horses in the UK, increased amounts of time spent outside the stable were associated with a decreased risk of stereotypic behavior (McGreevy et al., 1995c). In addition, Wickens (2009) found a negative relationship between the daily amount of turn-out and crib-biting behavior. Wickens (2009) also found that social contact with other horses (i.e. in the same enclosure) reduced the probability of crib-biting behavior. Survey studies conducted to investigate stereotypic behavior in race horses in Sweden (Redbo et al., 1998), and in Swiss horses of multiple breed types and

uses (Bachmann et al., 2003b) found that regular feeding of concentrates increased the risk of performing stereotypic behavior. Specifically, Redbo et al. (1998) demonstrated a positive relationship between the amount of concentrate and stereotypic behavior, including crib-biting, and a decreased risk of stereotypy with increased amount of roughage.

Visser et al. (2008) proved experimentally the associations between housing, social isolation and the performance of stereotypic behavior. In young, Dutch Warmblood horses previously naïve to stall housing, 22% of the horses housed individually in boxes were seen exhibiting crib-biting behavior whereas horses pair-housed in boxes did not begin performing stereotypic behavior (crib-biting, weaving or box walking). Although the data were not shown, Visser et al. (2008) indicated that after 12 weeks of stabling, performance of stereotypic behavior was still reversible in the majority of the horses exhibiting stereotypies. This finding stresses the importance of identifying behavioral problems early so that appropriate management changes can be made before crib-biting and other stereotypic behaviors become established. The approach implemented by Visser et al. (2008) appears valuable in obtaining a better understanding of the circumstances that elicit development of crib-biting behavior.

Certain breeds of horses may be more likely to exhibit stereotypic behavior, including crib-biting, than others. This was demonstrated by Bachmann et al. (2003b) in a survey of stereotypic behavior in Swiss horses in which Warmbloods and Thoroughbreds were at 1.8 and 3.1 times greater risk of performing stereotypic behavior, respectively, compared to other breeds. Albright et al. (2009) found that among US horses, Thoroughbreds were 3 times more likely to exhibit crib-biting behavior than Quarter Horses and 5 times more likely than Arabians. Vecchiotti and Galanti (1986) suggested the involvement of a genetic component in the performance of stereotypic behavior, as evidenced by the finding that one or more relatives in eight families of Thoroughbreds exhibited crib-biting behavior. Luescher et al. (1998) found a higher prevalence of crib-biting in geldings and stallions compared to mares, and a greater risk of crib-biting among Thoroughbred horses. Horses used for competitive disciplines such as racing, eventing, show-jumping, and dressage are often kept individually with limited free movement and social contact, and Thoroughbreds and Warmbloods are frequently engaged in these sports. Stallions also are frequently housed in individual enclosures to prevent accidental breeding and aggression.

Actual accounts of crib-biting behavior in other equid species are rare. For example, this author was not able to find documented cases of crib-biting in captive zebra. Personal communications with individuals working with large numbers of donkeys and mules indicate that occurrence of crib-biting in this species is infrequent, with only one donkey being reported to engage in a portion of the crib-biting sequence, i.e. anchoring its incisor teeth on fence boards (Windsor, personal communication; Taylor, personal communication). Donkeys, however, generally are not subjected to individual stall confinement and the high concentrate feeding that many horses are exposed to. It is

possible that the temperament and management of donkeys is protective against development of crib-biting. Boyd (1986) documented crib-biting in a zoo-kept female Przewalski's horse, and in a later publication (Boyd, 1991) referred back to this case cautioning that Przewalski's horses kept in small enclosures may begin crib-biting. Wood-chewing and coprophagy were observed in these horses in the small enclosures, but not when the horses were out on pasture (Boyd, 1986).

Interconnections between genetic and environmental factors, specifically interactions between gender and management, or breed and management, almost certainly play a role in the development of crib-biting behavior, and these relationships warrant further consideration in future experimental and epidemiological studies. Nonetheless, there is some evidence for a genetic predisposition in the display of the behavior (Vecchiotti and Galanti, 1986; Albright et al., 2009) and identification of specific genes responsible for crib-biting through pedigree analysis and association mapping should be pursued.

A few of the more recent survey studies have included questions related to owner and farm manager perceptions of stereotypic behavior in horses. British horse owners have demonstrated concern regarding the performance of stereotypic behavior with the majority of owners physically preventing horses from performing the behavior (McBride and Long, 2001). Cribbing straps were among the most frequently reported means of prevention. Horse owners and farm managers queried in a study conducted by Wickens (2009) also expressed concern about crib-biting behavior with 81% of owners indicating they had tried to stop the behavior. However, perceptions regarding the impact of the behavior on horse performance/learning, horse health, and monetary value of the animal were different between owners of non-stereotypic horses and those respondents currently owning/managing a crib-biter. In general, respondents presently owning/managing a crib-biting horse were less concerned about the behavior having a negative impact on learning, health, or monetary value. It appeared that perceptions about stereotypic behavior within the equine community at large may not coincide with those held by individuals having first-hand experience with crib-biting horses.

One additional aspect of crib-biting behavior that has received some consideration in recent epidemiological research is the question concerning whether horses learn to copy the behavior by watching or interacting with others. Currently, there is little evidence to support the belief that horses learn to perform stereotypic behavior by observing others. A small percentage of crib-biting horse owners (7%) in the study conducted by Wickens (2009) reported that a horse had started to crib-bite after another crib-biting horse had arrived at the farm. The management practices of those farms differed from one another with respect to primary housing, social contact, and hours of turn-out. Thus, it would be difficult to determine whether horses are in fact copying the behavior or if the behavior is the result of exposure to common management factors, specifically those factors previously demonstrated to be associated with an increased risk for crib-biting behavior. Albright et al. (2009) reported that only 1% of horses surveyed started

to crib-bite after the arrival of a crib-biting horse. On the other hand, Nagy et al. (2008) found an increased risk of stereotypic behavior (crib-biting and weaving) in horses exposed to stereotypic neighbors. Interestingly, it was the presence of a weaving neighbor that increased the risk of crib-biting. It has been suggested (Murphy and Arkins, 2007; Ninomiya, 2007) and more recently demonstrated (Krueger and Heinze, 2008) that familiarity with other horses and dominance hierarchies between horses may be important factors in the ability of horses to learn or copy a particular behavior by observation. Subsequent empirical and epidemiological investigation is needed prior to reaching a conclusion about the ability of horses to imitate stereotypic behavior through observation.

Cross-sectional studies are somewhat limited in their ability to determine cause and effect associations between management factors and crib-biting behavior. Many horses included in such studies may already be established in the behavior. Horses purchased or brought onto the farm already exhibiting crib-biting behavior may have developed the behavior as a result of previous management rather than from exposure to their present environment. Nonetheless, cross-sectional studies have been helpful in identifying the prevalence of, and in generating additional hypotheses about, stereotypic behavior. Prospective epidemiological research studies allow researchers to follow the development of behavior in young horses exposed to various management factors, and are the favored approach to identifying associations between environmental and horse-related variables and the performance of stereotypic behavior. However, the increased cost and time commitment associated with conducting longitudinal studies and the need for large sample sizes represent a definite challenge to researchers. Collaboration among equine scientists and epidemiologists from multiple institutions and regions may facilitate funding opportunities, enhance questionnaire and experimental design, and provide increased accessibility to farm managers/owners and available horses. Meta-analysis of existing studies may also be of value.

### **3. Neuroendocrine physiology and brain function in crib-biting horses**

The repetitive and persistent nature of stereotypic behavior has led authors in the past to describe such behavior in horses as "obsessive compulsive disorder" or OCD (Luescher et al., 1991; Shuster and Dodman, 1998). However, because obsessions involve recurrent, intrusive thoughts, a capability that horses are not known to possess, the terms "compulsive disorder" (Luescher et al., 1998), and "stereotypic behavior" (Mills and Nankervis, 1999) are preferred. Nonetheless, implication of the serotonergic system in compulsive disorders in both humans and horses represents a commonality between the two species in the underlying pathology of such repetitive or stereotyped behavior patterns. Serotonin reuptake inhibitors have been used to treat compulsive disorders in humans (Bandelow, 2008) and have been reported to reduce stereotypic behavior in horses (McDonnell, 1998). However, Lebelt et al. (1998) expressed uncertainty regarding whether these

drugs selectively affect stereotypic behavior or result in changes in behavior by way of a general sedative effect. [Lebelt et al. \(1998\)](#) did find a trend for lower basal serotonin levels in crib-biting compared to non-stereotypic horses, suggesting that the serotonergic system of crib-biters may differ from that of non-crib-biting horses. The precise role of serotonin in the development or maintenance of the behavior remains unclear, however, and the results obtained by [Lebelt et al. \(1998\)](#) have yet to be confirmed or refuted through additional experimental studies of the serotonergic system in crib-biting horses.

Endogenous opioids have been suggested to facilitate and reinforce stereotypic behavior ([Dodman et al., 1987](#); [Gillham et al., 1994](#); [Zanella et al., 1996](#)). In a study conducted by [Dodman et al. \(1987\)](#), infusion of opioid antagonists reduced crib-biting behavior, lending support to this hypothesis. Similarly, [McBride and Cuddeford \(2001\)](#) demonstrated a reduction in crib-biting behavior by administering naloxone, but the authors suggested that a general sedative effect of the opiate antagonist might have influenced performance of the behavior. Measurement of plasma  $\beta$ -endorphin in crib-biting horses has produced conflicting results. [Gillham et al. \(1994\)](#) reported significantly lower baseline concentrations of  $\beta$ -endorphin in crib-biting horses compared to non-crib-biting controls, whereas [Lebelt et al. \(1998\)](#) found 3 times higher basal  $\beta$ -endorphin concentrations in crib-biting horses. [Pell and McGreevy \(1999\)](#), however, found no significant difference in plasma  $\beta$ -endorphin concentrations between crib-biting and normal horses. [Lebelt et al. \(1998\)](#) and [Nicol \(1999\)](#) have suggested that peripheral plasma  $\beta$ -endorphin concentrations may not reflect concentrations in the central nervous system that would be responsible for producing behavioral changes. [Pell and McGreevy \(1999\)](#) have proposed that a failure to detect differences in plasma  $\beta$ -endorphin concentrations between crib-biting and normal horses may indicate greater sensitivity of opioid receptors in stereotypic horses.

Crib-biting behavior also has been proposed as a means to alleviate a horse's stress. In a study conducted by [Lebelt et al. \(1998\)](#), heart rate and nociceptive threshold were lowered in horses during periods of crib-biting. In their discussion, the authors suggest that the increased perception of the aversive stimulus may indicate a reduced state of arousal. This finding challenges the idea that crib-biting results in the release of endogenous opioids since  $\beta$ -endorphin induced analgesia would be expected to increase the nociceptive threshold. [McBride and Cuddeford \(2001\)](#) reported a significant reduction in plasma cortisol concentration following bouts of crib-biting, providing further evidence that the act of crib-biting may reduce stress. [McGreevy and Nicol \(1998b\)](#) found higher mean baseline concentrations of cortisol in crib-biting compared to normal horses, but prevention of the behavior via removal of the crib-biting surface, did not result in a rise in cortisol concentration. Subsequent studies have found no significant differences in plasma ([Pell and McGreevy, 1999](#); [Clegg et al., 2008](#)) or salivary ([Pell and McGreevy, 1999](#)) cortisol between crib-biting and control horses, suggesting that levels of arousal in stereotypic and normal horses are similar. There is some evidence suggesting crib-biting

horses react more strongly to acute stressors ([Minero et al., 1999](#); [Bachmann et al., 2003a](#)) compared to their non-crib-biting counterparts. In addition, [Minero et al. \(1999\)](#) found that heart rate and general activity of crib-biting horses returned more quickly to basal levels following application of the stressor, providing additional support that the behavior may serve as an adaptive response to stress. However, interpretation of the findings obtained from these studies is difficult and remains controversial. Results may be confounded by individual differences in temperament, reactivity and life experiences of the crib-biting and non-crib-biting horses enrolled in such studies. An inherent limitation in many of these studies is that measurements of cortisol have been obtained in mature horses with an established history of performing the behavior rather than in horses just developing the behavior. Although [McGreevy and Nicol \(1998b\)](#) observed higher cortisol concentrations in crib-biters, a result that may imply a heightened stress response in the stereotypic horses, the authors suggested that longitudinal studies would be necessary to establish whether development of crib-biting had been successful in reducing already elevated concentrations of stress hormones.

Research aimed at addressing the role of neuroendocrine physiology and brain function in the development and continued performance of stereotypic behavior is further complicated by the interrelationships between the hypothalamus–pituitary–adrenal (HPA) axis and reward systems within the brain. [Cabib et al. \(1998\)](#) found that stress induces significant changes in dopamine (DA) receptor densities within the mesoaccumbens and nigrostriatal systems in mice. In inbred strains of mice, these stress-induced changes in dopamine neurophysiology have been associated with the development of stereotypic behavior ([Cabib and Bonaventura, 1997](#)). More recently, [McBride and Hemmings \(2005\)](#) reported significantly lower DA D1-like receptor sub-types in the caudate nucleus (dorso-medial striatum; DMS) and significantly higher DA D1-like and D2-like receptor sub-types in the nucleus accumbens (ventral striatum) of crib-biting horses. Due to the involvement of basal ganglia and dopamine pathways in instrumental task learning specifically goal-directed learning and response–outcome processes, [Hemmings et al. \(2007\)](#) and [Parker et al. \(2008\)](#) proposed that basal ganglia dysfunction and alterations in dopamine physiology in crib-biters would be expressed as aberrant or impaired learning task performance. [Hemmings et al. \(2007\)](#) demonstrated that horses exhibiting crib-biting behavior required significantly more unreinforced trials to reach extinction criterion (i.e. stereotypic horses continued to perform button presses without receipt of the food reward), and it was suggested that this perseverative responding might be indicative of basal ganglia dysfunction. In the study by [Parker et al. \(2008\)](#), learning performance within a free-operant instrumental choice paradigm was compared between crib-biting horses and non-stereotypic horses. Crib-biting horses failed to choose a more immediate reinforcer demonstrating difficulty of the crib-biters to effectively learn the response–outcome contingency. These studies are among the first to examine and provide evidence of a behavioral correlate for neurophys-

iologic dysregulation in crib-biting horses. Investigating differences in learning ability between crib-biting and non-stereotypic horses, specifically within response-outcome paradigms offers a promising, non-invasive approach to addressing questions pertaining to the role of brain and neuroendocrine physiology in the performance of crib-biting behavior in horses. For further discussion of the role of the basal ganglia dopamine pathway in the development of equine stereotypy, see [McBride and Hemmings \(2009\)](#).

#### 4. Gastrointestinal irritation and crib-biting behavior

Free-ranging horses spend a large proportion of their time grazing and foraging. In contrast, domesticated horses, particularly elite performance horses, are often fed high concentrate, relatively low forage diets to meet the increased energy demands associated with their competitive lifestyles. Concentrate and forage rations are often delivered only 2 times per day, thus subjecting horses to longer periods of feed deprivation. Feed deprivation can result in gastric ulceration due to increased exposure of the squamous mucosal lining to gastric acidity ([Murray and Eichorn, 1996](#)). Gastrin, a peptide hormone secreted into the blood, is a potent stimulator of gastric acid secretion ([Katz, 1991](#)), and in horses, [Smyth et al. \(1989\)](#) observed a greater and more prolonged gastrin response to the feeding of pelleted and sweet feed diets compared to ad libitum hay feeding. Several studies have demonstrated associations between concentrate feeding and crib-biting behavior ([Kusunose, 1992](#); [Gillham et al., 1994](#); [Redbo et al., 1998](#); [Waters et al., 2002](#)).

It has been suggested that crib-biting behavior may be an adaptive response to gastric acidity and that the act of crib-biting may raise gastric pH as a result of increased flow of alkaline saliva ([Nicol, 1999b](#)). [Moeller et al. \(2008\)](#) demonstrated that salivation is stimulated with crib-biting, which lends support to this theory. Crib-biting behavior has recently been associated with gastric ulceration in foals, with gastric ulceration and inflammation present in 60% of crib-biting foals compared to 20% of non-crib-biting foals ([Nicol et al., 2002](#)). In addition, crib-biting foals had greater severity of ulceration and inflammation upon initial endoscopic examination ([Nicol et al., 2002](#)). In the same study, the stomach condition of foals consuming a diet containing an antacid improved and there was a trend toward reduced duration of crib-biting in supplemented foals. In mature horses, long-term treatment with antacids has been shown to reduce the frequency of crib-biting ([Mills and Macleod, 2002](#)), particularly in the period post-feeding. Crib-biting horses also have been found to have lower basal and post-feeding gastric pH compared to that of non-crib-biters ([Lillie, 2004](#)). In the study conducted by [Mills and Macleod \(2002\)](#), integrity of the gastric mucosa was not examined, thus it is unclear whether the reduction in crib-biting frequency observed in mature horses consuming an antacid diet was due to an increase in gastric pH alone or to an overall improvement in stomach condition. The underlying cause of lower gastric pH in crib-biting horses observed in the study by [Lillie \(2004\)](#) has not been determined. [Wickens \(2009\)](#) recently conducted a study

to examine the integrity and function of gastric mucosa in mature horses with a history of crib-biting behavior, but found no differences in the number or severity of squamous mucosal lesions between crib-biting and normal horses maintained on pasture. However, serum gastrin response to concentrate feeding was found to be higher in crib-biting horses compared to controls, providing some additional evidence that gastrointestinal physiology may be altered in horses exhibiting crib-biting behavior. It was suggested that gastrin-stimulated acid secretion may be enhanced in crib-biting horses due to greater G cell numbers or increased secretory capacity of the existing G cells, but this idea can only be confirmed through further investigation involving mucosal biopsies and molecular genetic techniques. It would be interesting to discover whether pathways involved in gastric acid secretion are upregulated in crib-biting horses. Additional studies employing continuous recordings of gastric pH in conjunction with repeated blood sampling for determination of basal and post-feeding serum gastrin concentrations in crib-biting and non-crib-biting horses may also be helpful in determining whether the gastrointestinal environment of crib-biting horses differs from that of normal horses.

Fermentation of concentrate feeds in the cecum and large intestine is known to reduce hindgut pH in horses ([Rowe et al., 1994](#)). In a study conducted by [Johnson et al. \(1998\)](#), increasing the amount of concentrate fed to horses resulted in the appearance of aberrant oral behaviors, such as wood-chewing, and reductions in fecal pH. Accumulation of lactic acid in the hindgut of horses was reduced by the addition of virginiamycin to the diet ([Rowe et al., 1994](#)), and supplementation with virginiamycin was shown to increase fecal pH and reduce the performance of abnormal oral behavior in horses receiving concentrate feed ([Johnson et al., 1998](#)). However, [Moeller et al. \(2008\)](#) contended that crib-biting was not one of the oral behaviors reported in the study by [Johnson et al. \(1998\)](#). A recent study conducted by [Freire et al. \(2008\)](#) found no effect of virginiamycin supplementation on crib-biting behavior. Thus, the authors suggested that established crib-biting behavior in adult horses may not be influenced by hindgut acidosis.

Horses with gastric mucosal injury exhibit bruxism and behavioral signs of colic ([Murray, 1998](#)), thus appearing that horses are able to detect gastric acidity and mucosal damage, or at least the pain it likely induces. Pain is known to bring about changes in dopaminergic activity ([Wood, 2004](#)), and [Hemmings et al. \(2007\)](#) postulated that visceral discomfort in horses may play an important role in the establishment of oral stereotypy through alteration of basal ganglia programming. It seems probable that a complex interrelationship between gastrointestinal and brain physiology is involved in the etiology of crib-biting behavior and further research in this area is warranted.

#### 5. Motivation to crib-bite and attempts to stop the behavior

Many owners attempt to physically prevent horses from performing crib-biting behavior ([McBride and Long, 2001](#); [Wickens, 2009](#)). Specific methods used to stop the behavior, with varying success, include removal of crib-

bing surfaces and application of repellents or electric wire, cribbing straps and muzzles, aversion therapy (Baker and Kear-Colwell, 1974) and the surgical removal of the paired omohyoideus and sternothyrohyoideus muscles and transection of the accessory nerves, a procedure known as modified Forssell's technique (Delacalle et al., 2002). The primary problem with these methods is that they fail to address the underlying causes of crib-biting behavior and may further reduce equine welfare (McBride and Cuddeford, 2001; Nagy et al., 2009), particularly if the behavior serves a function in stress reduction or alleviation of gastrointestinal discomfort. Short-term prevention of crib-biting behavior using a cribbing strap has been shown to increase crib-biting rate upon removal of the device (McGreevy and Nicol, 1998c). It was suggested that this post-inhibitory rebound reflected an increase in internal motivation to crib-bite during the period when the behavior was thwarted. McGreevy and Nicol (1998c) stated that behaviors that display this pattern of motivation may be considered functional to the horse. Houpt et al. (2005) demonstrated that crib-biting horses will work to gain access to a crib-biting surface and the results suggested that crib-biting horses valued the behavior nearly as much as they valued food.

The use of pharmacological agents in the treatment of crib-biting behavior has to some extent been successful in stopping or reducing the behavior (Dodman et al., 1987; McDonnell, 1998; Rendon et al., 2001) but requires constant infusion/administration, which would increase costs and labor inputs on farms. Moreover, the side effects and toxicity levels of such compounds have not been adequately studied in horses. Previous authors have recommended that management of crib-biting horses should be targeted toward removal of the causal factors as opposed to prevention through physical means. Increasing opportunities for horses to engage in natural foraging and social behavior is probably the best approach in attempting to prevent the development of crib-biting behavior and shows some promise for reducing frequency and duration of the behavior in established crib-biters (Redbo et al., 1998; Parker et al., 2008a; Wickens, 2009).

## 6. Conclusion

Experimental and survey research studies conducted within the past 15 years have provided a wealth of knowledge regarding the potential causal factors involved in crib-biting behavior. This information has been used extensively to help increase the awareness within the equine community on how the routine management of horses can affect their behavior and welfare. These studies have also given professionals engaged in the study of equine behavior a framework from which to generate additional hypotheses and research questions related to the development and continued performance of crib-biting behavior. Some of the specific areas meriting additional investigation include the use of learning tasks in assessing the role of brain function and further study of the gastrointestinal environment in crib-biting horses, application of genetic techniques to identify specific genes involved in the behavior, the

potential interactions between genetics and management, and the role of observational learning in the performance of crib-biting behavior. Ethologists and welfare scientists should continue to seek a multidisciplinary approach to address questions related to crib-biting behavior, including the use of behavioral and physiological measures, as well as application of epidemiological research methods. Furthermore, collaboration among equine scientists is encouraged to facilitate knowledge and resource sharing.

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