Journal of Veterinary Behavior 59 (2023) 8–14

Contents lists available at ScienceDirect

Journal of Veterinary Behavior

journal homepage: www.journalvetbehavior.com

Gaping for relief? Rein tension at onset and end of oral behaviors and head movements in unridden horses

Marie Eisersiö[a,*], Jenny Yngvesson[b], Elke Hartmann[b], Agneta Egenvall[a]

[a] Department of Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, Uppsala, Sweden
[b] Department of Animal Environment and Health, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, Skara/Uppsala Sweden

ARTICLE INFO

Article history:
Received 26 August 2021
Revised 30 August 2022
Accepted 10 November 2022
Available online 17 November 2022

Keywords:
Avoidance behavior
Bitted bridle
Equine welfare
Horse-rider interaction
Negative reinforcement
Rein tension

ABSTRACT

Pressure from the bit in the horse's mouth, rein tension, likely feels unpleasant to the horse due to sensitive oral tissues. Through trial and error, the horse may learn how to adjust their behavior in order to avoid, diminish or cease uncomfortable sensations from the bit. We hypothesized that oral behaviors and head movements in response to rein tension have the function to avoid or escape the rein tension. The study objective was to assess in what way oral behaviors and head movements affect rein tension and determine the magnitude of rein tension at the onset and end of these behaviors. Twenty Warmblood horses were fitted with a bitted bridle and subjected to 8 trials of backing up in response to a rein tension signal with the handler standing next to the horse's withers. The rein tension signal was gradually increased and then immediately released when the horse stepped back. A rein tension meter and video recordings were used for data collection. Linear mixed models were used for the statistical analysis. There was a decrease in mean rein tension (sum of left and right rein) from onset to end for open mouth ($P < 0.001$, from 19 to 11 Newtons (N), biting on the bit ($P = 0.004$, from 11 to 5 N), and head upward ($P = 0.024$, from 16 to 12 N), while there was an increase in rein tension associated with head forward ($P = 0.015$, from 27 to 37 N) and head downward ($P < 0.001$, from 17 to 46 N). Our results suggest that horses will open their mouth, or bite on the bit, to alleviate the oral tissues from pressure; move the head upward to avoid rein tension and move the head forward or downward to increase rein tension, likely in a presumed attempt to break free from the pressure applied. The horse's oral behaviors and head movements during training can be used to gain a greater understanding of how the horse perceives the magnitude of rein tension.

Introduction

Research suggests that horses may show evasion or escape behavior in response to rein tension, or pressure in the mouth from the bit (Quick and Warren-Smith, 2009; Christensen et al., 2011; Górecka-Bruzda et al., 2015). The function of evasive and escape behavior are to avoid or escape a situation that is perceived as threatening, that is, one that is making the horse feel mentally and/or physically uncomfortable (Hall and Heleski, 2017). Escape behavior has the function to get away from, or diminish, the influence of aversive stimuli. If escape behavior is negatively reinforced, by definition, the behavior leads to a reduction of the aversive stimulus, and it will become a learned avoidance behavior performed to avoid the aversive stimulus (McGreevy and McLean, 2010). For example, a horse pulling on the reins is likely a learned avoidance behavior attempted by the horse to gain more freedom of movement through longer/looser reins (Górecka-Bruzda et al., 2015).

Rein tension can cause discomfort and stress for the horse since applying tension on the reins means that the bit is pressing on sensitive oral tissues (McLean and McGreevy, 2010b; Hall and Heleski, 2017; Mellor, 2020). One way to determine if the magnitude of rein tension applied is compromising the horse's welfare is to study rein tension in relation to behavioral parameters

* Address for reprint requests and correspondence: Marie Eisersiö, SLU, Institutionen för kliniska vetenskaper Box 7054, 750 07 Uppsala.
E-mail address: marie.eisersio@slu.se (M. Eisersiö).

https://doi.org/10.1016/j.jveb.2022.11.009

(König von Borstel et al., 2017). Christensen et al (2011) found a correlation between a mean rein tension of 10 Newtons (N) and frequencies of conflict behavior (e.g., open mouth in combination with lifting/tilting the head) when the horses were pulling against short side reins to reach a food bucket (maximum rein tension 40 N). Likewise, Piccolo and Kienapfel (2019) reported that the horses displayed less conflict behavior without a rider when the horses' (voluntary) mean maximum rein tension was approximately 7.5 N on each side rein compared to with a rider (mean maximum 24 N in each rein). These studies give an idea about how much rein tension horses are willing to accept, but to date we do not know what magnitude of rein tension the horse is comfortable with and what magnitude will trigger oral or head/neck behaviors. Likewise, it is, to our knowledge, not determined which behaviors function to reduce pressure from the bit. It is likely that certain behaviors will decrease rein tension, while some actions taken by the horse appear to potentially increase rein tension.

Nosebands are extensively used within the equestrian sport and, if fitted tightly, may sensitize the horse's mouth, making the horse more responsive to rein tension signals (Randle and McGreevy, 2013), and also prevent the horse from performing oral behaviors like opening the mouth (McGreevy, 2011). A tight noseband thus makes it difficult for the horse to move the jaw (McLean and McGreevy, 2010a) thereby diminishes the possibility of the horse to manipulate the bit. Giving the horse the opportunity to perform oral behavior may, to some extent, allow the horse to control where in the mouth bit pressure is applied. Hence, oral behavior can potentially prevent and alleviate the development of sore oral tissue. This is particularly important when considering that several studies have revealed that oral injuries connected to the use of bits, bridles, and nosebands are common in riding horses (Björnsdóttir et al, 2014; Uldahl and Clayton, 2019; Tuomola et al, 2021).

Our hypothesis was that oral behavior and head movements in response to a rein tension signal will be associated with either an increase or a decrease in rein tension and that behaviors decreasing rein tension will be more frequently displayed than behaviors increasing rein tension. The aims of the study were therefore to investigate how oral behavior and head movements affect rein tension and to determine the magnitude of rein tension at the onset and end of these behaviors.

Materials and method

Twenty Warmblood horses (7.5 years ± 3.4), used as school horses at an Equestrian Centre in Sweden, were included in the study. The horses were mainly used for dressage and jumping and were regularly checked for soundness and health by the staff veterinarian. Two weeks prior to data collection, all horses had an oral examination. Following intravenous sedation with 10-15 microgram /kg detomidine hydrochloride (Domosedan, Orion Pharma), a Haussmann gag was fitted and the oral cavity was thoroughly inspected by a veterinarian with expertise in equine dentistry. All horses passed the oral examination and were included in the study.

An aisle (7×2 m) in a grooming area of the Equestrian Centre was used for the study. All horses were tested once with a bitted bridle and once with a halter in a randomized order. For this study, only data from the bridle treatment were used. All horses wore their own bridle with a correctly fitted snaffle bit in terms of length, thickness, and tightness of side pieces. Four horses had straight bits, 5 horses had single jointed snaffles, and 11 horses had double-jointed snaffles. The diameter of the bits was between 13-20 mm closest to the bit rings. The noseband of the bridle was removed completely.

The rein tension meter

Rein tension data were collected using a custom-made rein tension meter consisting of 1 load cell for each rein (Futek, CA, USA) that was wired to amplifiers and an inertial measurement unit (IMU, x-io technologies, Bristol, UK). The measuring range of the load cell was 0-500 N and the weight was 20 g. The IMU weighed 46 g, had a resolution of 10 bit and a 3.1 V battery. Rein tension data were sampled at 100 Hz. The load cells of the rein tension meter were fastened on the reins (flat leather reins with leather stoppers, 15 mm wide) by pinching the rein between metal plates using screws and bolts. Before bridling the horse, the reins with the rein tension meter were attached to the bit, and the amplifier box and IMU were taped onto the crown piece of the bridle. To confirm that the voltage output from the rein tension meter was stable, the rein tension meter was calibrated before and after the experiment, using ten known weights ranging from 0.2-10 kg.

Experimental setup

The study was initially designed for studying the characteristics of rein tension signals (Eisersiö et al, 2021a) and the learning process of a rein tension signal for backing up the horse (Eisersiö et al, 2021b). Therefore, the study design involved the application of a rein tension signal to elicit a backing response, using the principles of negative reinforcement (i.e., instant removal of bit pressure for stepping back reinforces this behavior and increases the likelihood of the horse stepping back again).

During data collection, the handler (first author, right-handed) stood on the left side of the horse, near the horse's withers (Figure 1). The trial began with a 2 minutes rest period with the handler and horse standing still on the aisle. The handler then picked up the reins, lifting the arms and placing the hands above the horse's withers while shortening the reins. The handler then gradually increased rein tension, closing the hands, exerting pressure on the reins, until the horse stepped back with at least 1 front leg. If the horse performed other behaviors than stepping back, rein tension was sustained (and gradually increased) until the horse stepped back. The handler stayed next to the horse's withers by stepping back along with the horse. As soon as the horse

Figure 1. Handler position. Horse standing with loose reins in the picture to the left, and rein tension signal applied in the picture to the right.

Table 1
The ethogram used for behavioral annotation describing the onset and end for each behavior.

Category	Behavior	Onset of behavior	End of behavior
Head movement	Upward	Head begins to elevate	Head stops moving upward
	Downward	Head begins to lower	Head stops moving downward
	Forward	Nose begins to move forward	Nose stops moving forward
	Backward	Nose begins to move towards the chest	Nose stops moving towards the chest
	Toss	A quick upward movement begins	Head is returned to start position
Oral behavior	Biting on bit	Horse begins to bite on the bit	Horse stops biting on the bit
	Open mouth	Visible gap between upper and lower jaw begins	Upper and lower jaw closes

stepped back, rein tension was immediately released by the handler opening and lowering the hands. The rein tension signal to step back was repeated 8 times with 1 minute-intervals. In between the backing events, the horse, and handler stood still on the aisle. After the 8 backing up trials, the horse and handler stood still on the aisle for 2 minutes.

A video camera recorded the horse's behavior and horse-handler interactions from the left side of the horse during treatment (Canon Legria HF R806, Canon Inc, Tokyo, Japan, 25 Hz). The rein tension meter was synchronized with the video recordings at the beginning and end of the treatment by pulling on the left rein tension meter 5 times (not affecting the horse's mouth) in front of the camera to create tension peaks that could be identified both in the video and in the rein tension data set.

Data extraction

Using the video recordings, the time intervals representing the rein tension signals and the horse's behavior were annotated at video frame level. The onset of the rein tension signal was annotated when the handler had shortened the reins and held the hands in place above the horse's withers. The moment when the handler started to lower the hands was annotated as the release of the rein tension signal.

The oral behaviors recorded were open mouth and biting on the bit, while head movements recorded were head upward, head downward, head forward, head backward, and head toss (Table 1). The onset and end of each behavior was annotated during each rein tension signal. The video sequence for each rein tension signal was first viewed at normal speed to register behaviors. The video was then viewed again and the frames at onset and end of each behavior were identified (Table 1). The onset of a behavior was the point in time when the horse started making the first movement that initiated the subsequent behavior, while the end of a behavior was when the behavior stopped. For example, the onset of head backward was the point in time when the horse's nose started to move inward, towards the horse's chest, and the end of head backward was when the nose started to move forwards again, even if the horse's nasal plane was still behind the vertical. Head upward, head downward, and open mouth can be seen in Video 1.

Data analysis

The protocols from the video recordings and the rein tension data were imported into Matlab (MathWorks Inc, MA, USA) and analyzed using a custom-written code. Descriptive statistics (mean, median, range, interquartile range (IQR)) of rein tension data (in N) were calculated for each of the 8 rein tension signals and each behavior, including extraction of the magnitude of rein tension at the onset and end of each behavior as well as the time duration (in s) of each behavior. The data were then imported into R Studio (version 1.2.5019, R Studio, MA, USA) for statistical analysis (R packages tidyverse, lme4, lmerTest, emmeans). The sum of left and right rein tension was used for analysis.

In order to determine if there was a significant difference between the onset and end rein tension for each behavior, linear mixed models were applied for each of the behaviors (onset to end models). The outcome variable was rein tension and the explanatory variable was time point with onset and end on different levels, modelled as a fixed effect. Horse and the interaction between horse and trial were included as random variables. For the open mouth model, the biting on the bit model, and the head upward model, only the interaction between horse and trial was included as a random variable to avoid overfitting those models. The R code can be found in the supplementary material.

Linear mixed models were also used to compare the magnitude of rein tension at the onset of the rein tension signal with the onset of the registered behaviors, as well as comparing onset rein tension between the behaviors. Linear mixed models were likewise applied, to determine if there was a significant difference in end rein tension among behaviors. Thus, the outcome variables were the rein tension at the onset of behaviors and the rein tension signal in one model (onset model) and rein tension at the end of behaviors in another model (end model). The explanatory variables were behavior (oral and head movement), and the rein tension signal in the onset model, and only behavior in the end model. The explanatory variables were fixed effects with behavior and the rein tension signal on different levels within the same variable for the onset model and only behavior on different levels within the same variable in the end model. Horse and the interaction between horse and trial were modelled as random variables in both models.

Rein tension data were not normally distributed and plots of Pearson's residuals were used to determine whether log-transformation or square root transformation was most suitable for each model. The transformation for each model can be found in Tables 3 and 4. Least square means and contrast *P*-values were computed for all level combinations. Contrasts were Tukey adjusted for multiple comparisons and the *P*-value limit was set to <0.05.

Results

Behavior was analyzed for 20 horses, subjected to 8 rein tension signals each, yielding 160 rein tension signals and 199 behaviors in total. Oral behavior and/or head movement during the rein tension signal was displayed by 18 of the 20 horses. Open mouth and head upward were the most common behaviors; displayed 77 times (17 horses) and 38 times (15 horses), respectively. Head backward was the least common behavior; displayed 15 times (8 horses). Head forward was shown 24 times (11 horses), head downward 22 times (9 horses) and biting on the bit 23 times (9 horses). The behavior head toss only appeared twice and was excluded from further analysis. Open mouth was shown in 34 % of the rein tension signals (in 54 of 160 rein tension signals) and head upward in 23 % of the rein tension signals . Head backward was shown in 9 %, head forward in 13 % and head downward and biting on the bit in 14 %

Table 2
Descriptive statistics of the sum of left and right rein tension (N) at the onset and end of each behavior and the rein tension signal. Data include behavior from 18 horses responding to 8 trials of a rein tension signal for backing up.

Behavior	Minimum		1st Quartile		Median		Mean		3rd Quartile		Maximum	
	Onset	End	Onset	End	Onset	End	Onset	End	Onset	End	Onset	End
Open mouth	5	0	12	5	18	10	21	15	28	19	82	104
Biting on bit	3	0	6	2	8	4	12	6	15	7	36	29
Head upward	2	1	7	7	12	11	18	13	31	16	49	47
Head backward	5	0	8	8	12	14	22	15	20	19	89	34
Head forward	6	10	18	23	25	36	29	40	37	51	95	92
Head downward	6	14	13	30	16	46	20	56	23	85	52	155
Rein signal	0	0	3	1	4	2	5	3	6	4	33	19

of the rein tension signals. Open mouth or biting on the bit was sometimes displayed simultaneously with one of the head movements. Likewise, head forward and head downward did to some extent overlap, but generally only 1 head movement at the time was present.

Biting on the bit had the lowest median onset rein tension, followed by head upward and head backward (Table 2). Biting on the bit also had the lowest median end rein tension, while head forward and head downward had the highest median end rein tension (Table 2). Figure 2 shows the difference in rein tension between onset and end for each of the behaviors. The median duration was less than 1 second for all behaviors (IQR 0.5-1.5 s) except biting on the bit that had a median duration of 2.5 s (IQR 1.5-3.5 s).

The onset to end models, comparing rein tension at the onset and end of each behavior, showed that rein tension decreased significantly from the onset to the end during the behaviors open mouth, biting on the bit, and head upward (Table 3). On the contrary, rein tension increased significantly from the onset to the end during head downward and head forward. There was no significant difference in rein tension between the onset and end for head backward.

The onset model showed that there was a significant difference between rein tension at the onset of the rein tension signal and the onset of each behavior (Table 4). The rein tension at the onset of the behavior biting on the bit was significantly lower than at the onset of head forward and open mouth. The rein tension at the onset of head upward was also significantly lower than the rein tension at the onset of head forward. The end model showed

Table 3
Least square means and confidence intervals for rein tension (N) at the onset and end of each behavior, calculated from each of the onset to end models. Rein tension was square root transformed in the open mouth, biting on the bit, head upward, and head forward models and log transformed in the head backward, and head downward models. Data include behavior from 18 horses responding to 8 trials of a rein tension signal for backing up. R code and output (including random effects) can be found in the supplementary materials.

Behavior	Event	Estimate	SE	lower CI	upper CI	*P*-value
Open mouth	Onset	19	2	16	23	<0.001
	End	11	1	9	14	
Biting on bit	Onset	11	2	7	14	0.004
	End	5	1	3	7	
Head upward	Onset	16	2	12	20	0.024
	End	12	2	8	15	
Head backward	Onset	13	5	6	29	0.381
	End	10	4	4	22	
Head downward	Onset	17	3	12	24	<0.001
	End	46	7	33	64	
Head forward	Onset	27	5	17	38	0.015
	End	37	6	26	50	

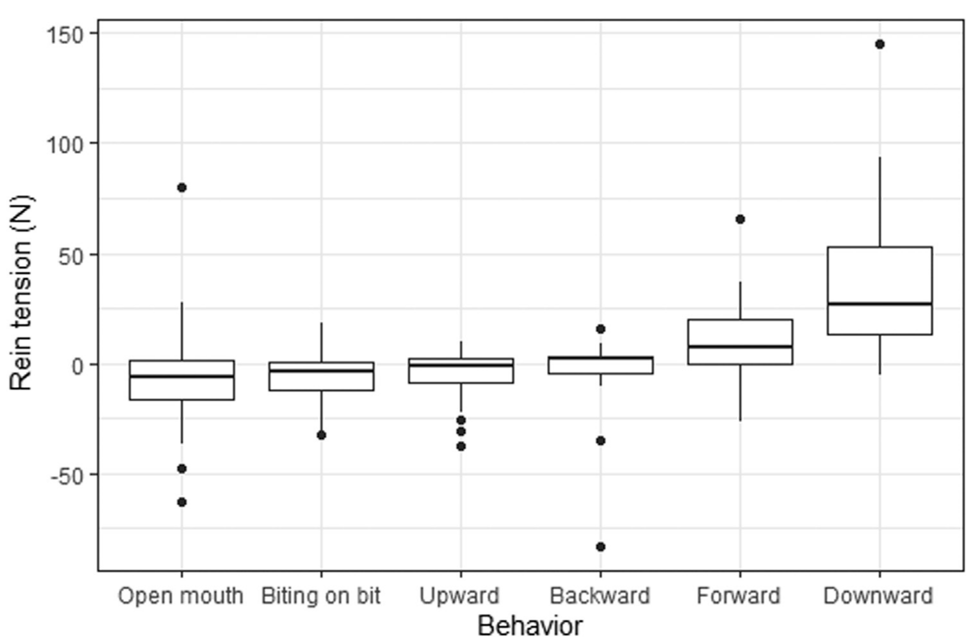

Figure 2. The mean rein tension (N) difference between end and onset of behavior. The onset rein tension has been subtracted from the end rein tension. A negative rein tension value indicates that end rein tension was lower than the onset rein tension, while a positive rein tension value signifies that end rein tension was higher than the onset rein tension. Number of horses displaying the behavior and number of observations were: Open mouth 77 times/17 horses, biting on the bit 23 times/9 horses, head upward 38 times/15 horses, head backward 15 times/8 horses, head forward 24 times/11 horses and head downward 22 times/9 horses.

Table 4
Significant contrasts from the onset model and the end model. Estimates are back-transformed and show the estimated difference in rein tension (N) between the variables. Rein tension was log transformed in the onset model and square root transformed in the end model. The first alternative listed has a higher rein tension. *P*-values have been Tukey-adjusted for multiple comparisons. Data include behavior from 18 horses responding to 8 trials of a rein tension signal for backing up. R code and output (including random effects) can be found in supplementary materials.

Model	Contrast		Estimate	SE	lower CI	upper CI	*P*-value
Onset	Head upward	Rein signal	8	1	4	13	<0.001
	Head backward	Rein signal	9	2	2	16	0.008
	Head downward	Rein signal	11	2	4	19	<0.001
	Head forward	Rein signal	20	3	9	30	<0.001
	Biting on bit	Rein signal	5	1	1	9	0.017
	Open mouth	Rein signal	12	1	7	16	<0.001
	Head forward	Head upward	11	4	1	22	0.033
	Head forward	Biting on bit	15	4	4	26	0.001
	Open mouth	Biting on bit	7	2	2	12	0.003
End	Head downward	Head upward	36	6	20	53	<0.001
	Head downward	Head backward	37	6	21	54	<0.001
	Head downward	Biting on the bit	43	5	27	59	<0.001
	Head downward	Open mouth	38	5	22	54	<0.001
	Head forward	Head upward	24	5	10	37	<0.001
	Head forward	Head backward	25	5	10	39	<0.001
	Head forward	Biting on the bit	30	5	17	44	<0.001
	Head forward	Open mouth	25	4	12	38	<0.001

that the rein tension at the end of head downward and head forward was significantly higher than at the end of all other behaviors (Table 4).

Discussion

The behaviors open mouth, biting on the bit, and head upward were associated with a significant decrease in rein tension from onset to end, while head downward and head forward were associated with a significant increase in rein tension from onset to end. Open mouth and head upward were the most common behaviors, displayed by most horses, and thus, behaviors decreasing rein tension were more common than behaviors increasing rein tension. Rein tension at the onset of the rein tension signal was significantly lower than at the onset of each of the recorded behaviors, that is, rein tension had to increase significantly, to about 10 N (approximately 5 N in each rein), before an oral behavior (biting on the bit onset median rein tension 8 N) or head movement (head upward/backward onset median rein tension 12 N) was displayed. This suggests that the behaviors were indeed provoked by the rein tension signal. Certain behaviors were elicited at a lower magnitude of rein tension than other behaviors; biting on the bit and head upward were initiated at significantly lower rein tension than head forward. Since the behaviors head forward and head downward increased rein tension, the rein tension as these behaviors ended was significantly higher compared to when the other behaviors ended.

Pressure from the bit can cause discomfort and pain (Mellor, 2020) and, therefore, it may seem puzzling why horses sometimes perform behaviors that increase rein tension. The behaviors head downward and head forward both increased rein tension, yet most likely with the presumed expectation that these behaviors would lead to a longer/looser rein. When a horse moves the head forward and/or downward in a quick motion, it can result in the rider losing the grip on the reins (Górecka-Bruzda et al., 2015). Thus, moving the head forward and/or downward have likely been manifested through previous successful trial-and-error learning in getting relief from rein tension by pushing against the bit. In other words, it is plausible that the function of these behaviors is to try to alleviate the pressure from the bit. It should also be noted that the behavior head forward commenced at a higher rein tension than the other behaviors. This could indicate that rein tension had to reach a certain magnitude before the horses were motivated to briefly increase mouth pressure in order to potentially completely release it.

Head upward and head backward showed intermediate levels of rein tension both at onset and end (Tables 2 and 3). Since the rein tension signal was gradually increased, these behaviors may reflect the horses' attempts to avoid being subjected to excessive bit pressure by altering their head carriage before stepping back. Our results suggest that if the horse is moving the head upward or backward, away from the pulling force on the mouth, the function of those behaviors is likely to avoid or decrease rein tension. Similarly, it seems that open mouth and biting on the bit either had the function to reduce the pressure from the bit or that these behaviors appeared when rein tension reached a certain magnitude and then terminated as rein tension magnitude was lowered again. Nevertheless, our results suggest that the function of these behaviors was to alleviate the oral structures from bit pressure.

The rein tension at the onset of the behavior open mouth had an IQR of 12-28 N (sum of left and right rein, Table 2), or an IQR of approximately 6-14 N in each rein. This magnitude of rein tension is fairly low when compared with results from rein tension studies of ridden horses (median 22-40 N, sum of left and right rein) at the trot (Kuhnke et al., 2010; Eisersiö et al., 2015). This result is comparable to the magnitude of voluntary rein tension measured during trotting in unridden horses (Piccolo and Kienapfel, 2019), stationary unridden horses (Christensen et al, 2011) and unridden horses backing up from a single rein (Fenner et al., 2017). When a rider has contact on the reins, rein tension is constantly varying due to the horse's gait and stride cycle (Egenvall et al., 2015; Piccolo and Kienapfel, 2019), and perhaps a mean rein tension of 10 N in each rein is a fairly accurate limit of how much mouth pressure the horse can be comfortable with. Yet, individual differences among horses have to be considered as, for example, temperamental traits like tactile sensitivity and reactivity/fearfulness differ among horses and have been found to have a significant effect on learning performance, specifically responsiveness to negative reinforcement (Lansade and Simon, 2010). It is also likely that rein tension signals may need to escalate beyond 10 N to elicit a desired response from the horse in, for example, a fear-eliciting situation like the encounter of a fear-inducing stimulus or in a new environment.

The horse opening the mouth in response to bit pressure has been suggested by earlier research to be an indicator of discomfort when performed in response to excessive rein tension

(Manfredi et al, 2010; Christensen et al., 2011). Given that rein tension decreased during open mouth, the function of this behavior is likely to gain comfort or, at least, reduce discomfort. However, many riders choose to fit the noseband of the bridle tightly to inhibit horses from opening their mouth (McGreevy et al., 2012), likely in an attempt to make the horse more responsive to the bit and hide unwanted mouth behavior during dressage competition (Fenner et al., 2016). In other words, a tight noseband may mask pain and discomfort and may also give an unfair competitive advantage to riders relying on sustained and restrictive pressures in place of appropriate and ethical training methods. The horses in our study did not wear nosebands and could freely open their mouth. Considering that the magnitude of rein tension measured at the onset of open mouth was lower than measured rein tension in ridden horses (e.g., Kuhnke et al., 2010; Eisersiö et al., 2015), it is likely that also ridden horses may feel a need to open their mouth to reduce discomfort on the oral structures while the noseband is restricting them.

A limitation of this study is that the horses' intra-oral behaviors could not be recorded. Manfredi et al (2010) conducted a fluoroscopic study of unridden horses' intra-oral behaviors when standing in stocks and being subjected to a steady contact of 25 ± 5 N rein tension in each rein. They recorded the behaviors lifting the bit, retracting the tongue, and bulging the tongue over the bit using fluoroscopic images. In future rein tension studies it would be interesting to investigate rein tension at the onset and end of different types of intra-oral behaviors in more detail using fluoroscopic technique.

When interpreting the results from this study it should be kept in mind that the rein tension applied was not constant. The handler increased rein tension to motivate the horse to step back and then immediately released rein tension as the horse stepped back. Thus, if an oral behavior and/or head movement coincided with the handler's actions, the magnitude of rein tension partly reflects the handler's application and release of rein tension. However, an advantage of our study design, that is, of gradually increasing the rein tension, was that it provided a large spectrum of rein tension magnitudes. Furthermore, it enabled recording of onset rein tension for several behaviors and allowed to determine which behaviors were more frequently initiated at lower and higher magnitudes, respectively.

It would be interesting to perform a similar study in ridden and unridden horses comparing rein tension at the onset and end of different behaviors for horses wearing a bitted bridle with and without a noseband or different bits, including bitless bridles. Studying rein tension at the onset and end of different behaviors reveals the potential function of the behavior and thus provides an indication of how the horse experiences the rein tension applied.

Conclusion

Open mouth or biting on the bit was associated with a decrease in rein tension from onset to end, suggesting that these behaviors were performed to alleviate the oral tissues from the bit pressure. The head moving upward decreased rein tension, indicating that the horses avoided the escalating rein tension by altering their head carriage. Conversely, the head moving forward or downward was associated with an increase in rein tension from onset to end, suggesting that the horses tried to push against the bit pressure to escape. The results from this study yield information about how different magnitudes of rein tension affect horse behavior and how the horse's behavior affects rein tension. Thus, the horse's behavior provides an indication of how the horse experiences rein tension and can potentially reflect the magnitude of rein tension the horse may be comfortable with. Monitoring horse behavior in response to rider and handler signals should be addressed throughout all training.

Authorship statement

The idea for the paper was conceived by Marie Eisersiö. The experiments were designed and performed by Marie Eisersiö, Agneta Egenvall and Jenny Yngvesson. All authors contributed to the data analysis. The paper was written by Marie Eisersiö. All authors contributed to improve the paper and approved the final version.

Acknowledgments

We want to thank the staff at the Equestrian Centre, Torun Wallgren for assistance during data collection, Lars Roepstorff for expertise on the rein tension meter and data visualization, Anna Byström for creating the Matlab script for synchronizing the example video with the rein tension data, and Kate Fenner for constructive feedback on the ethogram. The funding for this study was provided by the Swedish University of Agricultural Sciences through a Career Grant for Agneta Egenvall.

Ethical considerations

The study was approved by the Animal Ethics Board in Uppsala, Sweden, Dnr 5.8.18-02567/2019.

Conflict of Interest

There are no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jveb.2022.11.009.

Video 1. The application of the rein tension signal and the horse's behavioral response. Behaviors shown are head upward, head downward, and open mouth. The magnitude of rein tension can be seen below the video. The playback speed was reduced for improved perception of the events.

References

Björnsdóttir, S., Frey, R., Kristjansson, T., Lundström, T., 2014. Bit-related lesions in Icelandic competition horses. Acta Vet. Scand. 56, 40.

Christensen, J.W., Zharkikh, T.L., Antoine, A., Malmkvist, J., 2011. Rein tension acceptance in young horses in a voluntary test situation. Equine Vet. J. 223 (43), 223–228. doi:10.1111/j.2042-3306.2010.00151.x.

Egenvall, A., Roepstorff, L., Eisersiö, M., Rhodin, M., van Weeren, R., 2015. Stride–related rein tension patterns in walk and trot in the ridden horse. Acta Vet. Scand. 57, 89. doi:10.1186/s13028-015-0182-3.

Eisersiö, M., Rhodin, M., Roepstorff, L., Egenvall, A., 2015. Rein tension in 8 professional riders during regular training sessions. J. Vet. Behav.: Clin. Appl. Res. 10, 419–426.

Eisersiö, M., Byström, A., Yngvesson, J., Baragli, P., Lanata, A., Egenvall, A., 2021a. Rein tension signals elicit different behavioral responses when comparing bitted bridle and halter. Frontiers in Vet. Sci. 8, 450. doi:10.3389/fvets.2021.652015.

Eisersiö, M., Yngvesson, J., Byström, A., Baragli, P., Egenvall, A., 2021b. A rein tension signal can be reduced by half in a single training session. Appl. Ani. Beh. Sci. 243, 105452.

Fenner, K., Yoon, S., White, P., Starling, M., McGreevy, P., 2016. The effect of noseband tightening on horses' behaviour, eye temperature, and cardiac responses. PLoS ONE 11 (5), e0154179. doi:10.1371/journal.pone.0154179.

Fenner, K., Webb, H., Starling, M.J., Freire, R., Buckley, P., McGreevy, P.D., 2017. Effects of pre-conditioning on behaviour and physiology of horses during a standardised learning task. PLoS ONE 12 (3), e0174313. doi:10.1371/journal.pone.0174313.

Górecka-Bruzda, A., Kosinska, I., Jaworski, Z., Jezierski, T., Murphy, J., 2015. Conflict behaviour in elite show jumping and dressage horses. J. Vet. Behav. 10, 137–146.

Hall, C., Heleski, C., 2017. The role of the ethogram in equitation science. Appl. Anim. Beh. Sci. 190, 102–110.

König von Borstel, U., Visser, E.K., Hall, C., 2017. Indicators of stress in equitation. Appl. Ani. Beh. Sci. 190, 43–56.

Kuhnke, S., Dumbell, L., Gauly, M., Johnson, J.L., McDonald, K., König von Borstel, U., 2010. A comparison of rein tension of the rider's dominant and non-dominant hand and the influence of the horse's laterality. Comp. Ex. Physiol. 1–7. doi:10.1017/S1755254010000243.

Lansade, L., Simon, F., 2010. Horses' learning performances are under the influence of several temperamental dimensions. Appl. Anim. Beh. Sci. 125, 30–37.

Manfredi, J.M., Rosenstein, D., Lanovaz, J.L., Nauwelaerts, S., Clayton, H.M., 2010. Fluoroscopic study of oral behaviours in response to the presence of a bit and the effects of rein tension. Comp. Ex. Physiol. 6, 143–148.

McGreevy, P.D., McLean, A.N., 2010. Equitation Science. Wiley-Blackwell, United Kingdom, pp. 87–88.

McGreevy, P.D., 2011. The fine line between pressure and pain: ask the horse. Vet. J. 188 (3), 250–251. doi:10.1016/j.tvjl.2010.10.011.

McGreevy, P., Warren-Smith, A., Guisard, Y., 2012. The effect of double bridles and jaw-clamping crank nosebands on temperature of eyes and facial skin of horses. J. Vet. Behav. 7 (3), 142–148.

McLean, A.N., McGreevy, P.D., 2010a. Ethical equitation: capping the price horses pay for human glory. J. Vet. Behav. 5 (4), 203–209. doi:10.1016/j.jveb.2010.04.003.

McLean, A.N., McGreevy, P.D., 2010b. Horse-training techniques that may defy the principles of learning theory and compromise welfare. J. Vet. Behav. 5, 187–195.

Mellor, D.J., 2020. Mouth pain in horses: physiological foundations, behavioural indices, welfare implications, and a suggested solution. Animals 10, 572. doi:10.3390/ani10040572.

Piccolo, L., Kienapfel, K., 2019. Voluntary rein tension in horses when moving unridden in a dressage frame compared with ridden tests of the same horses—a pilot study. Animals 9, 321. doi:10.3390/ani9060321.

Quick, J., Warren-Smith, A.K., 2009. Preliminary investigations of horses' (*Equus caballus*) responses to different bridles during foundation training. J. Vet. Behav. 4, 169–176.

Randle, H., McGreevy, P., 2013. The effect of noseband tightness on rein tension in the ridden horse. J. Vet. Behav. 8, e18–e19.

Tuomola, K., Mäki-Kihniä, N., Valros, A., Mykkänen, A., Kujala-Wirth, M., 2021. Bit-related lesions in event horses after a cross-country test. Front. Vet. Sci. 8, 651160. doi:10.3389/fvets.2021.651160.

Uldahl, M., Clayton, H.M., 2019. Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. Equine Vet. J. 51, 154–162. doi:10.1111/evj.12827.