The movement of the rider's hand related to the horse's behaviour and the stride cycle

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Ryttarens handrörelse relaterad till hästens beteende och stegcykeln

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Abstract

One way of signalling commands to the horse during riding is through applying tension on the reins to create bit pressure in the horse's mouth (Terada et al., 2006; Clayton et al., 2011). The skilfulness of the rider in using the hands when applying bit pressure has consequences both for the horse's performance and welfare (Manfredi et al., 2010). At the trot there are large vertical deviations of the horse's body which the rider must adjust and adapt to (Terada et al., 2006) and an unsteady hand due to inability to follow the horse's movement can be a source of discomfort and conflict behaviour in the horse (Heleski et al., 2009). By examining the rider's signals and the horse's behavioural expression, clues can be received about the horse's experience of its training. The aim of this project was to describe the rider's hand movement and the horse's head movement during sitting trot and to find relationships between these variables, the horse's behaviour, the rein tension and the stride cycle. The hypothesis was that the rider's hand will interact with the horse through the reins in a regular pattern correlated to the horse's head movement and stride cycle and that the horse will show behavioural responses to these interactions. Seven dressage horses were ridden in trot on a treadmill with an integrated force measuring system and infrared cameras registering the position of reflective markers on the horse's head and the rider's hands. Three horses wore a rein tension meter and all horses were studied for behavioural responses. Behavioural responses included changes in head-, ear- and tail position as well as gestures with the mouth. Ground reaction forces (GRF) were used to define the stride cycle. All data were normalised into 101 data points, 0-100 % of a stride cycle. From the normalised stride curves, range of motion, mean values and variation were calculated. The kinematic, behavioural and rein tension data were related to the stride cycle and examined for their general activity. The rider's hand movement and the horse's head movement followed the same movement pattern in the X- and Z-axis. Increased proportion of mouth behaviours, increased distance between the rider's hand and the horse's head as well as increased rein tension were all associated with the suspension phase at the trot. Behavioural registration combined with biomechanical measurement yields information about the horse's response to rider actions and is beneficial when evaluating training techniques and rider performance.

Sammanfattning

Ryttarens hand kan, genom tygeln, skapa ett tryck från bettet i hästens mun och detta är ett sätt att signalera sin vilja till hästen under ridning. Hur pass skicklig ryttaren är på att utföra denna signal med sin hand har konsekvenser för hästens välfärd och prestation. Vidare rör sig hästens kropp under trav i ett rörelsemönster som innebär stora vertikala förändringar och detta måste ryttaren anpassa sin kropp och framförallt sin hand till. Om handen inte följer hästens rörelser kan det skapa obehag för hästen och leda till konfliktbeteenden. Genom att analysera ryttarens signaler och hästens beteenderespons under ridning kan man hitta ledtrådar till hur hästen upplever träningen. Syftet med denna studie var att beskriva ryttarens handrörelser och hästens huvudrörelser under nedsutten trav och att hitta samband mellan dessa två variabler samt hästens beteende, tygeltrycket och stegcykeln. Hypotesen var att ryttarens hand interagerar med hästen genom tyglarna i ett regelbundet mönster korrelerat med hästens huvudrörelser och stegcykeln och att hästen kommer att visa beteenderespons på dessa interaktioner. Sju dressyrhästar reds i trav på en rullande matta med ett integrerat kraftmätningssystem. På hästarnas huvud och ryttarens händer fästes markörer vars position registrerades med hjälp av infraröda kameror. Tre hästar reds med tygeltrycksmätare och alla hästar studerades för beteenderespons, vilka inkluderade förändring i huvud-, öron- och svansposition samt uttryck med munnen. Markens reaktionskraft (GRF) användes för att definiera stegcykeln. All data normaliserades till 101 datapunkter, 0-100 % av stegcykeln. Utifrån de normaliserade stegkurvorna beräknades rörelseomfång, medelvärden och variation. Ryttarens handrörelser och hästens huvudrörelser följer samma rörelsemönster i X- och Z-led. En ökad proportion munbeteenden, ett ökat avstånd mellan ryttarens hand och hästens huvud samt ett ökat tygeltryck hörde alla samman med svävningsfasen i trav. Beteenderegistrering kombinerat med biomekaniska mätningar ger information om hästens respons på ryttarens signaler och är värdefullt vid utvärdering av träningstekniker samt ryttarens prestation.

Introduction

Horseback riding is a very popular recreational activity as well as a profession for a large number of people in the world and ridden exercise is a daily activity for many horses. Signalling to the horse is generally done through applying tension on the reins that leads to pressure in the horse's mouth via the bit (Terada et al., 2006; Clayton et al., 2011), touching the horse's sides with the legs and by changing the weight distribution in the saddle (Steinbrecht 1995). Applying tension on the reins is a signal to the horse to regulate its movement (Clayton et al., 2011), in other words, the signal is used to control the horse's speed, direction and degree of self-carriage (Manfredi et al., 2010) and through training, the horse can learn to respond to more and more subtle changes in rein tension (Terada et al., 2006). This is important to strive for since horses have sensitive oral tissues (Steinbrecht, 1995; Terada et al., 2006). Further, ulcers in the oral cavity are common in horses used for riding (Tell et al., 2008), possibly connected to the bit and/or the rider's use of the hand (Casey, 2007; Clayton et al., 2011). Subsequently, how skilful the rider is in using the hands on the reins has consequences both for the horse's performance and welfare (Manfredi et al., 2010), but science has not yet studied this relationship sufficiently (Clayton et al., 2011).

One of the characteristics of an independent seat on horseback is the relative stillness of the hand in relation to the horse's mouth (Terada et al., 2006). The relative stillness of the hands facilitates the communication between horse and rider (Terada et al., 2006) and according to Heleski et al. (2009) an unsteady hand can be the source of discomfort and conflict behaviour in the horse. Nevertheless, whether and when a horse displays conflict behaviour is very individual and some horses are more tolerant to inconsistencies of the aids than others (Heleski et al., 2009).

The trot is one of the equine gaits, consisting of symmetric diagonal footfalls with a suspension phase in between (Hinchcliff et al., 2008). According to Terada et al. (2006) this suspension phase generates large vertical deviations, or a bouncing motion, of the horse's body which the rider must adjust and adapt to. A rider that does not follow the horse's movement well may rely on the reins for support and balance (Terada et al., 2006; Heleski et al., 2009). In Terada et al. (2006) six experienced riders were studied at sitting trot. The distance between these riders' hip and the horse's bit varied significantly more than the distance between the bit and the rider's shoulder's or wrists. The shoulder joint and elbow joint flexed and extended as the trunk tilted forwards and backwards leading to the range of distance being significantly smaller between the bit and the rider's wrist compared to the rider's shoulder or hip. Terada et al. (2006) suggest that, in essence, the stabilization of the hand in relation to the bit is done this way. The rider's seat has been further examined by Byström et al. (2009).

Tension on the reins can be created both by the horse and the rider, either by the horse pushing its head against the direction of the rein pressure or the rider exerting pressure or pulling back on the reins (Clayton et al., 2011; Egenvall et al., 2012). Rein tension will therefore likely vary depending on the style of riding, the level of training of the horse and the expertise of the rider (Clayton et al., 2011). In Clayton et al. (2005) it was found that rein tension during horseback riding follows a regular pattern synchronized with the movement of the horse's body. Later, Clayton et al. (2011) studied unridden horses fitted with side reins at the trot and found that the rein tension still varied in a regular pattern, peaking at each diagonal stance phase. As the length of these side reins was shortened, more tension was applied by the horses due to a greater restriction of the head and neck. Tension on the reins increased the least when the most elastic material was used, since the elastics stretch when tension increases. The same principles would probably hold true for a rider applying non yielding rein tension on short reins. Further, in Rhodin et al (2009) it was found that restricting the horse's head and neck carriage, in essence changing the head and neck position, altered the stride length and back movement.

Studies of the behaviour of the horse in relation to rein tension and rider/handler interaction have been conducted before. Warren-Smith and McGreevy (2007) investigated the horse's behaviour and training progress during long reining while using either negative reinforcement only or positive and negative reinforcement together. Von Borstel el al. (2009) studied the horse's behaviour during the over flexed head position 'rollkur'. Heleski et al. (2009) studied the effect of supplementary reins as a training aid on the amount of rein tension and conflict behaviour in the horse and in a study by Christensen et al. (2011) naïve horses were tested for habituation to rein tension. In the latter study, the horses learned to avoid the rein tension and it was proposed that horses find rein tension aversive since in this study, rein tension also correlated with expression of conflict behaviour. In Blokhuis et al. (2008) horses showed more evasive behaviour after their riders had been through a seat improvement programme. One explanation for this was that the riders were more demanding of the horses after completing the seat programme. More demands, in essence interactions, with the horse seem therefore to possibly lead to increased frequencies of evasive behaviour. As conflict or evasive behaviours several authors define tossing, shaking, turning or tilting the head, gaping, tail swishing and ears pinned back (de Cartier d'Yves and Ödberg, 2005; Blokhuis et al., 2008; Heleski et al., 2009; Christensen et al., 2011).

The Fédération Equestre Internationale (FEI) is the controlling authority of all international dressage competitions providing rules, guidelines and standards for competition. In their guidelines for the evaluation of contact and mouth problems (Fédération Equestre Internationale, 2011) it is stated that the contact with the bit should not be forced and the horse should not show resistance against the hand. Further, the marks should be deducted for open mouth/gaping, tongue hanging out and tilting of the head. These mentioned mouth behaviours are visible to the observer, but the horse can also display intra-oral behaviours as a reaction to bit pressure. By video recording horses' mouths using fluoroscopic images intra-oral behaviours while wearing a bit was registered by Manfredi et al. (2010). Recordings were made both with and without tension applied on the bit. Behaviours like mouthing the bit, retracting the tongue and bulging the tongue over the bit was more common when tension was applied, while a quiet mouth was less common. The authors believe that the behaviours retracting the tongue and bulging the dorsum of the tongue between the bit and the hard palate was likely displayed to relieve pressure on sensitive tissues in the mouth. Mouthing the bit was also more frequent when tension was applied, however this behaviour was considered desirable by Manfredi et al. (2010).

Since we use devices like the bit in the horse's mouth to control the horse during riding, the interactions between the horse and the rider needs to be examined. To receive clues of the horse's experience of its training, the behavioural response and expression of the horse should always be closely monitored. To learn more about the effect of riding on the horse it is then also important to describe why and when certain behaviour occurs.

Aim and hypothesis

The aim of this project was to describe the rider's hand movement and the horse's head movement during sitting trot and to find connections between these variables, the horse's behaviour, the rein tension and the stride cycle.

The hypothesis was that the rider's hand will interact with the horse through the reins in a regular pattern correlated to the horse's head movement and stride cycle and that the horse will show behavioural responses to these interactions.

Material and methods

Material

This study was part of a larger project made in Zurich (Rhodin et al., 2009). The study has ethical approval from the Animal Health and Welfare Commission of the canton of Zurich. Seven dressage horses competing at Grand Prix level (n=6) and Intermediaire level (n=1) were used. The horses were all Warmblood breed (height 1.70 ± 0.07 m), ridden by their usual riders and equipped with their own saddle and bridle with a snaffle bit and a cavesson. The cavesson was an English noseband and some horses wore a flash noseband as well. The riders were 2 males and 5 females (weight 78 ± 17 kg). All horses were examined by a veterinarian prior to the study to ensure soundness.

Study design

The trials were performed in a laboratory on a high speed treadmill (Mustang 2200) with an integrated force measuring system (Weishaupt et al., 2002). Each tested horse and rider had reflective markers with a diameter of 19 mm glued onto the skin or the clothes respectively on predetermined sites. Twelve infrared cameras (ProReflex, Qualysis) were used to register the position of the markers at the frame rate of 140/240 Hz for 12 (n=2) to 15 (n=5) seconds. In this study, reflective markers placed on the horse's head (cristae facialis – on the side and in the middle of the horse's head) and the rider's hands on both left and right side were used. The reflective markers reflect the movement of the designated area in three directions; the X-axis horizontally and positive in the horse's direction of motion (backwards and forwards motion), the Y-axis horizontally and positive to the left (side to side motion) and the Z-axis vertically and positive upwards (upwards and downwards motion) (Byström et al., 2010). The positions for the reflective markers are expressed in millimetres along the axis. Video recording, synchronized with the rest of the equipment, was used to capture the trials on film at a frame rate of 25 frames per second. A rein tension meter (Futek 2357 JR S-Beam mini load cell force sensor) (Reierstad, 2005) was only used on three of the seven horses due to technical problems. The tension meter was placed between the bit and the reins and a Computer Boards AD-converter was used to register the signal from the instrument. The load cell weighed 28 grams and was synchronised to the rest of the equipment. The horses were ridden in trot, with the neck raised, poll high and bridge of the nose slightly in front of the vertical. A qualified dressage judge declared when the horse was moving correctly and at that point the recordings begun. The horses were recorded in a speed series of 3-5 different speeds at the trot. The speed ranged from 2.7 m/s to 3.4 m/s, but never differed more than 0.6 m/s within the same horse.

Behavioural evaluation

Behaviour was registered from the video recordings of the horse's left side using continuous recording. The videotapes were studied in GOM player (www.gomlab.com). Each videotaped sequence was 12 (n=2) or 15 (n=5) seconds long and each film were first viewed at normal speed to determine what behaviours were present and approximately how often they occurred. The film was then viewed again studying each second frame by frame (25 frames per second). For each frame one or several behaviours were registered. The ethogram for horse behaviour contained the following behaviours (table 1): upper lip movement, lower lip movement, lips pressed together, mouth movement, gaping, nostrils widened and drawn back, ears pinned back, ears back, ears forward, ears to the sides, tail movement, head tilt and head shake. The rider's leg movements were also observed. Nose wrinkle and pressed lips was taken out of the material due to inability to adequately assess these behaviours from the films.

Ten per cent (1063 of 10350 frames) of the behaviours displayed with the mouth were out of sight due to a textile belt next to the treadmill. Depending on the height of the horse, if the horse lowered its head, the mouth ended up in the camera angle right behind the textile belt. Five horses had less than ten per cent of the mouth registrations missing (1 % - 8 %) and two horses had more than ten per cent of the mouth behaviour out of sight (22 % and 30 %). Since other behaviours were still in sight for registration, these frames were not excluded from the data, out-of-sight behaviours were considered as absent.

Table 1: Ethogram

Behaviour	Definition
Upper lip movement	Upper lip is drawn upwards or outwards, teeth visible
Lower lip movement	Lower lip is drawn downwards, teeth visible
Lips pressed together	Lips are pressed together
Gaping	Space is visible between upper and lower jaw
Mouth movement	Slight opening of the mouth or slight lip movement
Nose wrinkle	Nostrils widened and wrinkle displayed caudally
Ears pinned back	Ears pressed back and downward
Ears back	Ears angled backwards
Ears forward	Ears angled forwards
Ears to the sides	Ears angled to the sides
Tail movement	Rotating, or lateral or vertical movement of the tail
Head tilt	The head is held oblique
Head shake	The horse is throwing its head upward, downward or from side to side
Rider leg movement	The rider's heel or spur is touching the horse's sides

The horse's stride cycle

Ground reaction forces (GRF) were used to relate biomechanical and behavioural data to the stride cycle. The ground reaction force is the force exchanged between the ground and a body and in these data recordings reveal the timing of the horse's footfalls. In essence, the stride cycle consist of the first contact of the hoof, the duration of the stance, the lift off and the suspension phase. The stride cycles presented in the results show first contact and duration of the left diagonal on the ground (left front, LF, and right hind, RH), a suspension phase when all hoofs are in the air, the impact and duration of the right diagonal on the ground (right front, RF, and left hind, LH) and a suspension phase at the end. The front limbs bear more weight than the hind limbs and also remain in stance slightly longer than the hind limbs. The unit for the ground reaction forces is Newton. A trial of 15 seconds consisted of 17-19 strides and a trial of 12 seconds 14-16 strides depending on speed.

Data analysis

All data were normalised into 101 data points, 0-100 % of a stride, ranging from first contact of the left front hoof to just before next first contact of left front hoof, resulting in one full stride cycle including two stance phases and two suspension phases. Data from the reflective markers as well as behavioural data and rein tension data were analysed through custom-written code in Matlab (The MathWorks Inc.) and descriptively in Excel (MS Excel, Microsoft Corporation).

It was hypothesised that speed would not affect the variables in this study and the data from all trials were combined. To support this, the data with the lowest speed were compared graphically to the middle and highest speed, in total 3 comparisons per horse. The mean values of the trials were used as the data from each horse. From the averaged normalised stride curves range of motion (ROM), mean values and variation were calculated. The mean X- and Z-values from the reflective markers at the horse's head and the rider's hands were related to the stride cycle and examined for their general motion. The Y-values were not studied. The mean range of motion in the X- and Z-axis for the rider's hand and the horse's head movement of the individual horses and riders were calculated by subtracting the minimum values from the maximum values in the mean sample results for each horse. The variation in distance between the rider's hand and the horse's head was calculated by custom-written code in Matlab and the mean variation was determined and related to the stride cycle to see when increases and decreases of distance occurred. Due to poor data quality for the cristae facialis, only four out of seven horses were analysed graphically to describe the head movement and the variation in distance between the rider's hand and the horse's head. Rein tension data for the three horses were also calculated and correlated to the stride cycle as well as comparing the pattern for rein tension during the stride cycle with the behavioural response of the horse.

After being normalised, the behavioural data demonstrated the mean per cent behaviour in each of the 101 data points, expressing when during the stride cycle the behaviour was most frequent. When going through the data material behaviours associated with a certain phase in the stride cycle was of particular interest for comparative reasons. All behaviours expressed with the mouth (mouth movement, gaping, upper lip movement and lower lip movement) showed temporal association with the stride cycle and to facilitate the overview of this material they were assembled into one single category named "mouth behaviour". The descriptive statistics for the category mouth behaviour is therefore calculated on the mean values for mouth movement, gaping and upper and lower lip movement, instead of being gathered into one category from the beginning in the raw material. Confidence interval (95 %) was added for the mouth behaviour category.

Results

The seven rider-horse combinations performed 3-5 trials each, resulting in a total of 29 trials in sitting trot at speeds ranging from 2.7 m/s to 3.4 m/s. The number of strides was 14-16 strides for the 12 second recordings and 17-19 strides for the 15 second recordings yielding a total of 501 recorded strides. Due to poor marker data for the horse's head the diagrams displaying the horse's head movement are based on 18 trials from four horses with a total of 324 recorded strides. The results below are the mean values from the kinematic and behavioural recordings as well as the rein tension measurements.

The rider's hand movement and the horse's head movement

The rider's hand movement and the horse's head movement in the sitting trot follow the same movement pattern in the X-axis (forwards and backwards) in all horses and riders in all speeds of trot (see figure 1). Both the rider's hand and the horse's head are moving backwards in the suspension phase (around data point 0, 50 and 100) and forwards in the stance phase (around data point 25 and 75). The diagrams show the mean distribution of the mean values from the reflective markers. The right hand moves more in the forwards and backwards direction and the right side of the horse's head is further back than the left side.

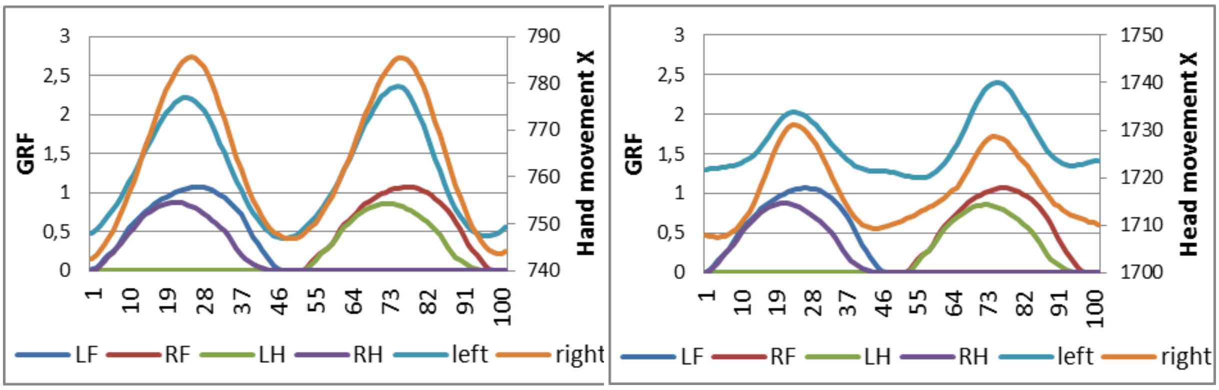

Figure 1: Ground reaction forces and the rider's hand movement in the X-axis (left figure) and ground reaction forces and the horse's head movement in the X-axis (right figure) during the stride cycle. The diagrams are showing the mean distribution of values from the reflective markers of 29 vs. 18 trials with seven vs. four horses. GRF begins with first contact of left front limb and right hind limb. The X-axis is horizontal and positive forwards. Rider hand movement left vs. right hand mean 761 vs. 763 mm, max 779 vs. 786 mm, min 747 vs. 743 mm, SD 11 vs. 14 mm, ROM 32 vs. 43 mm. Horse's head movement left vs. right side mean 1727 vs. 1717 mm, max 1740 vs. 1731 mm, min 1720 vs. 1707 mm, SD 6 vs. 7 mm, ROM 20 vs. 24 mm.

The rider's hand movement and the horse's head movement in trot follow the same pattern in the Z-axis (upwards and downwards) in all horses and riders in all speeds of trot (see figure 2). Both the rider's hand and the horse's head are moving upwards in the suspension phase and downwards in the stance phase. The horse's head is moving more upwards on the right side.

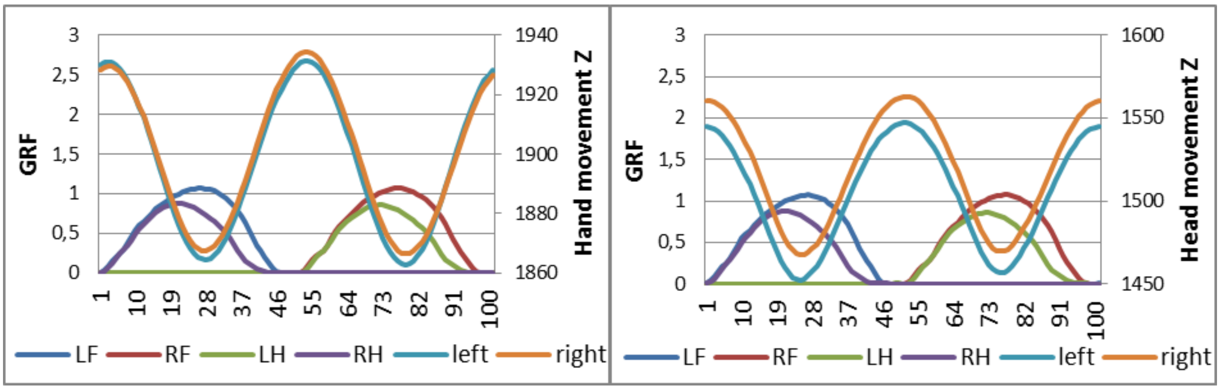

Figure 2: Ground reaction forces and the rider's hand movement (left figure) and GRF and the horse's head movement (right figure) in the Z-axis during the stride cycle. The diagrams are showing the mean distribution of values from the reflective markers of 29 vs. 18 trials with seven vs. four horses. GRF begins with first contact of left front limb and right hind limb. The Z-axis is vertical and positive upwards. Rider hand movement left vs. right hand mean 1898 vs. 1900 mm, max 1931 vs. 1934 mm, min 1863 vs. 1866 mm, SD 24 vs. 23 mm, ROM 69 vs. 68 mm. Horse's head movement left vs. right side mean 1504 vs. 1519 mm, max 1547 vs. 1563 mm, min 1452 vs. 1468 mm, SD 32 vs. 33 mm, ROM 95 vs. 96 mm.

Table 2 shows the range of motion of the rider's hand and the horse's head in the X- and Z-axis for each horse and rider.

Table 2: Mean values of the range of motion (SD for the stride cycle) in millimetres for the rider's hand and the horse's head in X and Z and variation in distance between the rider's hand and the horse's head on the left and right side.

	Horse and rider	1	2	3	4	5	6	7
Range (SD)	Hand left X	31 (10)	37 (11)	58 (18)	35 (9)	36 (11)	53 (16)	27 (9)
	Hand right X	73 (24)	39 (12)	46 (14)	44 (12)	43 (13)	68 (22)	29 (9)
	CF left X	14 (3)	28 (8)	26 (8)	31 (9)	-	29 (8)	17 (5)
	CF right X	25 (9)	23 (7)	-	28 (10)	-	24 (8)	-
	Hand left Z	78 (26)	94 (30)	65 (21)	68 (24)	81 (27)	100 (31)	71 (24)
	Hand right Z	83 (27)	95 (31)	70 (22)	69 (23)	73 (24)	80 (26)	68 (22)
	CF left Z	89 (29)	120 (38)	103 (29)	94 (32)		92 (32)	96 (8)
	CF right Z	86 (29)	123 (40)	-	98 (33)	106 (34)	101 (34)	-
	Distance rider hand left – horse head left	17 (5)	8 (2)	32 (8)	29 (9)	-	22 (7)	17 (5)
	Distance rider hand right – horse head right	46 (14)	13 (3)	-	27 (8)	22 (7)	35 (10)	-

The variation in distance between the rider's hand and the horse's head

The distance between the rider's hand and the horse's head varied between 17 and 32 mm for the left hand and 13-46 mm for the right hand in the seven horses and riders (See table 2). Maximum distance occurs at the suspension phase and minimal distance at the stance phase (figure 3). The diagram (figure 3) is showing the mean variation in distance from four horses in 18 trials. Distance varied more between the right hand and the right side of the head than the left side and there was also a shorter distance between the right hand and the right side of the horse's head.

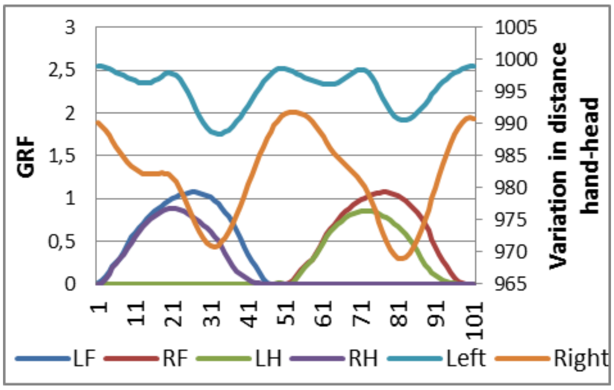

Figure 3: Ground reaction forces and variation in distance (mm) between the rider's hand and the horse's head (cristae facialis) during the stride cycle. The diagrams are showing the mean distribution of values from the reflective markers of 18 trials with four horses. Left side mean 995 mm, max 999 mm, min 988, range 11 mm, SD 3 mm. Right side mean 982 mm, max 992 mm, min 969 mm, range 23 mm, SD 7 mm.

Behavioural recordings

Mouth movement was the most frequently occurring mouth behaviour (mean 23 % ± 13 %) and gaping the most infrequent (mean 2,4 % ± 2,5 %). The horse always displayed a predefined ear position and the most common one was ears forwards, 59 %. Tail movement was displayed in three out of four recordings for one horse and one out of four recordings for one other horse. Unusual behaviour was head tilt, head shake and ears pressed back. There were no visible leg signals from the riders (see table 3).

Table 3 shows the proportions of behavioural expression during the stride cycle in the seven horses, based on mean value of the (averaged) within-stride values of each horse. The values thus represent the mean values of all horses; in essence, the maximum values are the maximum of the mean values from the seven horses and the same is true for the other values as well.

Table 3: The mean proportions displayed behaviour from 29 trials with seven horses

Behaviour (%)	Mean	SD	Max	Min	1st quartile	3rd quartile
Upper lip	5,7	7,0	15,9	0,0	0,7	10,2
Lower lip	2,3	3,4	8,5	0,0	0,0	3,5
Mouth movement	22,9	12,7	43,5	10,0	12,9	31,1
Gaping	2,4	2,5	7,1	0,0	0,7	3,4
Ears pressed back	0,0	0,1	0,1	0,0	0,0	0,0
Ears back	28,1	35,6	100,0	0,0	3,0	38,0
Ears forwards	59,0	33,9	100,0	0,0	43,6	84,0
Ears to the sides	12,7	10,2	27,8	0,0	5,2	18,3
Tail movement	2,4	5,9	15,7	0,0	0,0	0,5
Head tilt	0,5	1,1	2,9	0,0	0,0	0,4
Head shake	0,0	0,0	0,1	0,0	0,0	0,0
Rider leg	0,0	0,0	0,0	0,0	0,0	0,0

The mouth behaviours (at least one of mouth movement, upper and lower lip movement and gaping) were assembled into one category and 95% confidence intervals were added (see figure 4). These behaviours were mainly displayed during the suspension phase. The mean distribution of behaviour for each individual horse was first calculated and then a mean curve of all horses was created from those values. The diagrams of the horse’s behaviour (figure 4, 5 and 6) thus show the mean distribution of the behaviours during the stride cycle.

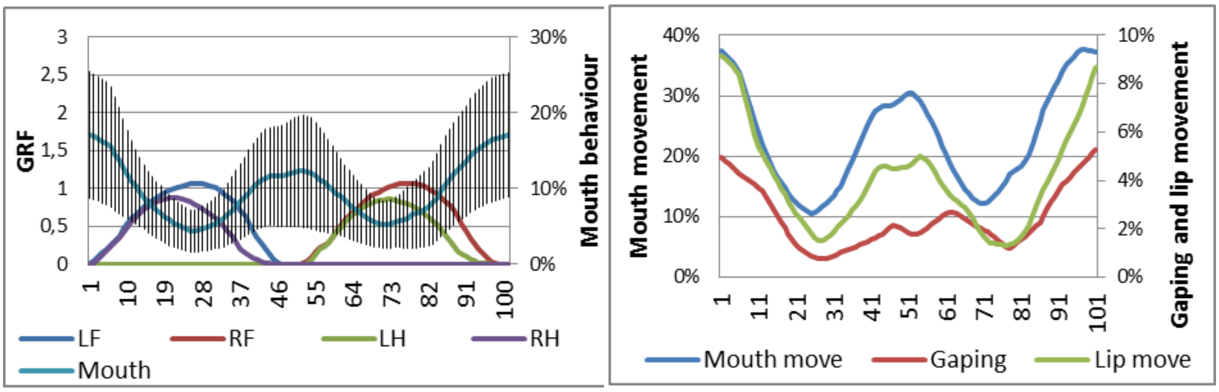

Figure 4: Ground reaction forces and the mean distribution of mouth behaviour (mean ± the width of the 95 % CIs) (left figure) and the mean distribution of the individual mouth behaviours; mouth movement, gaping and mean of upper and lower lip movement (right figure), during the stride cycle at the trot. The behavioural data are calculated on 29 trials with seven horses. The behaviours mainly appear in the suspension phase, around data point 0, 50 and 100. Mouth behaviour mean 9,8 %, max 17,2 %, min 4,4 %, SD 3,8 %. Mouth movement mean 22,9 %, max 37,7 %, min 10,6 %, SD 8,5 %. Gaping mean 2,4 %, max 5,3 %, min 0,7 %, SD 1,2 %. Upper and lower lip movement mean 4 %, max 9,2 %, min 1,3 %, SD 2,1 %.

Ear positions were always registered and each position mainly had long duration. Ears to the sides was shown all throughout the stride cycle, while ears back correlated slightly to the suspension phase and ears forward marginally to the stance phase (figure 5).

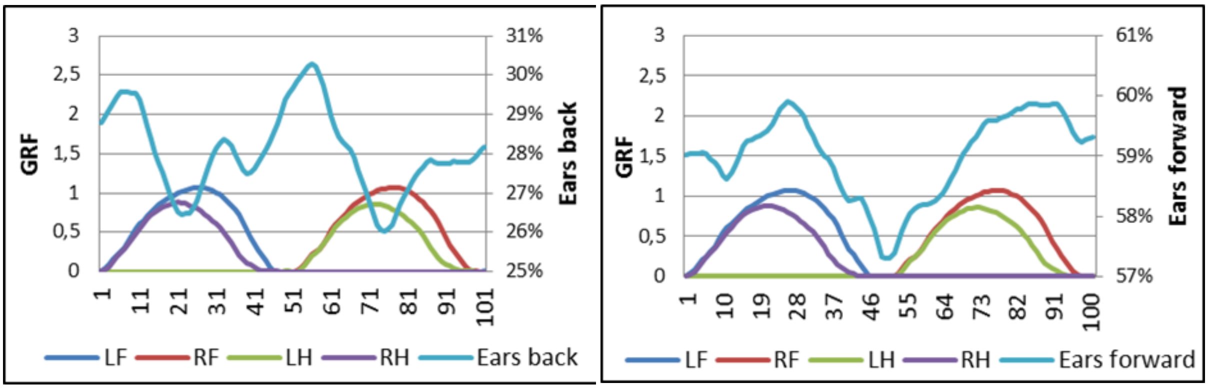

Figure 5: Ground reaction forces and mean distribution of ears back over the stride cycle (left figure). Ground reaction forces and mean distribution of ears forwards during the stride cycle (right figure). The diagrams are showing the mean distribution of values from the behavioural data of 29 trials with seven horses. Ears back mean 28 %, max 30 %, min 26 %, SD 1 %. Ears forward mean 59 %, max 60 %, min 57 %, SD 0,7 %.

Head tilt and tail movement appeared in low frequencies, had short duration and were mainly displayed at the suspension phase and in the first half of the stance phase (figure 6).

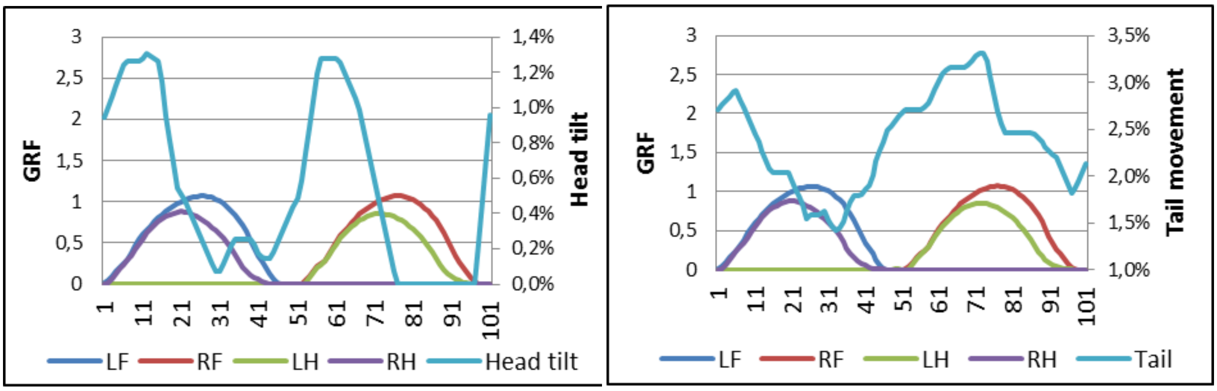

Figure 6: Ground reaction forces and per cent of tail movement during the stride cycle. The diagrams are showing the mean distribution of values from the behavioural data of 29 trials with seven horses. Head tilt mean 0,5 %, max 1,3 %, min 0 %, SD 0,5 %. Tail movement mean 2,4 %, max 3,3 %, min 1,4 %, SD 0,5 %.

Rein tension

Rein tension (kg) was recorded for three horses (figure 7 and 8). Rein tension increased in the suspension phase (around data point 0, 50 and 100) in horse 1 and 4 (figure 7 left and figure 8) and both in the suspension phase and the stance phase (around point 25 and 75) in horse 2 (figure 7 right). Mouth behaviour (mouth movement, upper and lower lip movement and gaping) was correlated with the increase in rein tension at the suspension phase. Both the amount of rein tension and the amount of mouth behaviour differed between the horses.

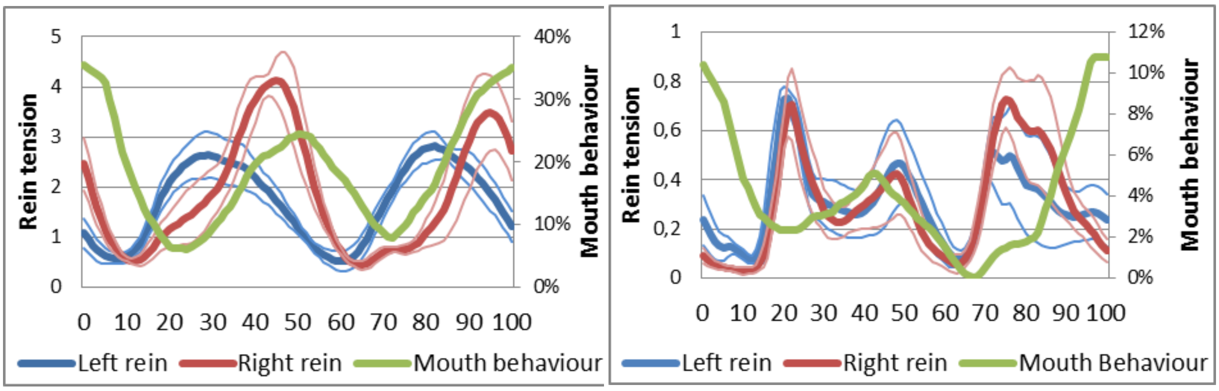

Figure 7: Rein tension (kg) and mouth behaviour an average stride cycle for horse 1 (left figure) and horse 2 (right figure). The diagrams are showing the mean distribution of rein tension (± SD) and mouth behaviour from 4 trials with one horse in each diagram. Horse 1 left and right rein mean 1,71 kg and 1,85 kg, max 2,82 kg and 4,14 kg, min 0,52 kg and 0,45 kg, SD 0,77 kg and 1,15 kg. Horse 1 mouth behaviour mean 19 %, max 35 %, min 6 %, SD 9 %. Horse 2 left and right rein mean 0,31 kg and 0,3 kg, max 0,73 kg and 0,73 kg, min 0,08 kg and 0,03 kg, SD 0,15 kg and 0,21 kg. Horse 2 mouth behaviour mean 4 %, max 11 %, min 0,02 %, SD 3 %.

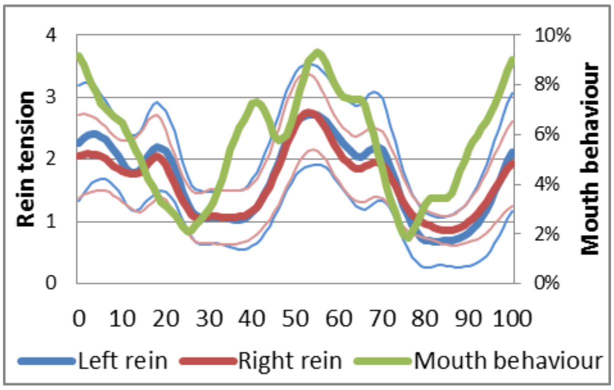

Figure 8: Rein tension (kg) and amount of mouth behaviour an average stride cycle for horse 4. The diagram is showing the mean distribution of rein tension (± SD) and mouth behaviour from 5 trials with one horse. Horse 4 left and right rein mean 1,68 kg and 1,63 kg, max 2,72 kg and 2,76 kg, min 0,68 kg and 0,86 kg, SD 0,63 kg and 0,52 kg. Horse 4 mouth behaviour mean 6 %, max 9 %, min 2 %, SD 2 %.

Discussion

Kinematics

The synchronisation between the rider's hand and the horse's head is important because it facilitates communication between the two (Terada et al., 2006) and unsteady hands can cause discomfort to the horse (Heleski et al., 2009). In this study, the rider's hand and the horse's head are synchronised in their movement in the X-axis and Z-axis. At each diagonal stance phase the horse's head and the rider's hand is moving downwards and forwards and at each suspension phase the horse's head and the rider's hand is moving upwards and backwards. However, the left and right side are not synchronised. The results from the mean curves suggests that the horse's head is slightly bent to the right and tilted to the left, i.e. the nose being drawn to the right side more instead of staying straight forward. This is likely an effect of the rider's right hand which is performing a larger movement in the X-axis than the left hand, affecting the horse to yield to the pressure signal.

When analysing the variation in distance between the horse's head and the rider's hand it is also evident that the synchronisation is not complete. There were larger fluctuations between the variables on the right side than on the left side and there was also a shorter distance in general between the right hand and the right side of the horse's head. This also indicates bending to the right and more interactions on the right side between horse and rider. Distance is increasing at the suspension phase and also displays a slight increase at the stance phase as evident by figure 3. Distance between the rider's hand and the horse's head will vary if the horse changes head position by raising or lowering the head or the rider changes hand position by moving the hands forwards or back at a different point in time than the horse. A constant distance between the rider's hand and the horse's head should indicate that the rider's hand follows the movement of the horse's head well and that the horse's head stays steady to the hand and in a constant head carriage.

One complication for analysing the variation in distance between the rider's hand and the horse's head is the placement of the reflective markers on cristae facialis on the horse's head. This placement yields limited information about the position of the horse's head since the cristae facialis is situated in the middle of the horse's head and there can be movement both above and below the marker. Several reflective markers on the horse's head would have been necessary to describe the horse's head movement and the rider's ability to follow it. Placing a marker near the horse's mouth as well as studying the marker of the atlas vertebrae would generate a more accurate picture of the horse's head movement and the rider's interaction with the hand. Another way to receive more information about the interactions between the horse's head and the rider's hand would be to compare these markers to for example the thoracic vertebrae six (the withers).

Rein tension

Rein tension is varied during the stride cycle, likely caused both by the rider pulling on the reins and the horse pushing against the bit as stated by Clayton et al. (2011). As mentioned before, the unridden horses wearing side reins in that study (Clayton et al., 2011) peaked in rein tension at each diagonal stance phase. The indication from these results is that the increase in rein tension at each diagonal stance phase is coupled to the horse's head moving downwards and forwards at that point. In this present study, rein tension peaked at the suspension phase in two out of three horses and in both the suspension phase and the stance phase in the third horse. One interpretation of these results is that peaks in rein tension at the stance phase is created by the horse and rein tension peaking at the suspension phase is created by the rider. Another interpretation is that peaks in rein tension at both stance and suspension are due to the rider's inability to follow the movement of the horse's head.

Since both the horse and the rider can be the initiator of increased bit pressure, combining rein tension data with the stride cycle seems essential when studying this concept. Furthermore, the interaction increasing bit pressure performed by one can lead to a counter response in the other. For example, increased bit pressure created by the rider can result in a counteraction by the horse to push its head against the bit pressure, subsequently increasing bit pressure even more (Egenvall et al., 2012). This can occur both in inexperienced horses using trial and error to get rid of bit pressure (Egenvall et al., 2012) and in experienced horses performing a learned behaviour that have gained them benefits in the past.

Behaviour

All horses performed some kind of mouth behaviour. These behaviours were mainly displayed at the suspension phase and are therefore likely connected to the rider's hand moving upwards and backwards, the increased rein tension and the increased distance between rider's hand and the horse's head. An increase in rein tension usually created a behavioural response with the mouth as seen in Manfredi et al. (2010). These authors referred to mouthing the bit when the horse was displaying mandibular and/or tongue movement without separating the incisors more than 1 cm and this was regarded as a desirable behaviour. This description sounds very similar to the mouth movements recorded in this study.

Clearly, the horse can react to bit pressure in many ways. Other reactions than the above mentioned is gaping or clenching the jaw shut, the first usually being regarded as a conflict or evasive behaviour (de Cartier d'Yves and Ödberg, 2005; Blokhuis et al., 2008; Heleski et al., 2009; Christensen et al., 2011) and the last being difficult to assess as an observer. Generally, riders prefer a mobile, soft mouth in their mount and this behaviour can be trained by teaching the horse to yield to the pressure from the bit (Karl, 2008). Too much bit pressure can, on the other hand, lead to gaping, clenching the jaw or other resistances in the horse (McLean and McGreevy, 2010).

The mouth behaviours had a clear correlation to the stride cycle by having large variations in amount of behaviour depending on phase in the stride cycle, while head tilt, ears back and tail movement only appeared slightly more often in the suspension phase. This can be explained by head tilt being a quiet uncommon behaviour and ears back mainly being displayed with long duration ranging over several stride cycles. Tilting the head, tail swishing and ears back can, however, be a sign of conflict or evasion (de Cartier d'Yves and Ödberg, 2005; Blokhuis et al., 2008; Heleski et al., 2009; Christensen et al., 2011) and should be studied further for correlations to rider interactions. Behavioural studies correlated to the stride cycle of the horse have additional potential. If behaviour is shown solely on one diagonal it could be a sign of physical discomfort in the horse or unevenness in the rider's interactions. Such analysis was, however, not within the scope of this study.

The hypothesis turned out to be true. The rider's hand did follow a regular movement pattern in the X-axis and the Z-axis correlated to the stride cycle and behavioural responses from the horse could be coupled to both the stride cycle and the movement of the hand. Using the hand to apply rein signals is an indispensable way of communicating and demanding obedience from the horse (Terada et al., 2006; Clayton et al., 2011). This kind of signal, however, has the potential to harm the horse's sensitive oral tissues and compromise its welfare (Manfredi et al., 2010), which is an important reason to further scrutinize the rider's use of the hand. The relative stillness of the hand is one of the difficulties of riding (Terada et al., 2006) and further studies should focus on finding more clues to how this can be achieved and taught to riders.

To assess an animal's welfare it is an important part to evaluate its behaviour. The horse's behaviour during riding should be a measure of the horse's welfare as a riding horse and of the quality of the riding. Since the rider's hand is responsible for a large part of the communication between horse and rider, the rider should always strive to improve his/her skills using the hands. Studies of the horse's behaviour in relation to the rider's signals are important, particularly the relationship between signals applied to the horse's mouth and the welfare of the horse needs further study.

Limitations of this study and sources of error

The fact that the horses were ridden in a speed series might have affected the results. No effect of speed was found for the other parameters, but the same speed would have been preferred to completely exclude that factor. To receive more accurate results in studies of the interactions between the horse's head and rider's hand more reflective markers on the horse's head should be utilized. Utmost care should also be taken in placing these markers on the exact same spot on both sides since measurements are conducted on very small variations in movement. To examine the placement of the markers, the files of the horses standing still could have been studied. Likewise, analysing the Y-values would have yielded additional information on the movement of the horse's head and the rider's hand.

The behavioural study could have been more refined. I would have preferred to be able to differentiate between the mouth behaviours more exactly. Since the video was studied frame by frame, mouth movement sometimes became gaping after a few frames and perhaps those mouth movements should have been registered as part of the gaping behaviour as well.

Enhanced sharpness in the quality of the video recordings would also have improved the behavioural recordings by showing the behaviours more clearly and also making registrations of facial expressions of the horse possible, especially the expressions displayed with the nose, eyes and lips. It would also have been preferred to have the horses ridden without a noseband or with the noseband very loosely attached, since mouth behaviour was of particular interest and can to some extent be hidden when the horse's mouth is restricted by a leather band. Further, the mouth behaviours were out of sight when the horse lowered its head due to the textile belt on the side of the treadmill resulting in missing registrations.

The rein tension data contributed a lot to the kinematic and behavioural data in understanding the relationships. Rein tension data for all the horses would have been very valuable in this study since it would have generated a more complete picture of the interaction between the rider's hand and the horse's head.

Conclusion

The rider's hand and the horse's head follow the same movement pattern in the X-axis and Z-axis at the trot. They are moving downwards and forwards at each stance phase and upwards and backwards at each suspension phase. There is, however, a variation in distance between the horse's head and the rider's hand and the right and left side differs in range of motion and movement pattern. Increases of rein tension at the stance phase seem to be coupled to the horse's head moving downwards and forwards, while increases in rein tension at the suspension phase probably is coupled to the rider's hand moving upwards and backwards. Studying rein tension data in relation to the stride cycle is therefore valuable. Mouth behaviours were mainly displayed at the suspension phase and are likely connected to the rider's hand moving upwards and backwards, the increased rein tension and the increased distance between the rider's hand and the horse's head. Behavioural registration combined with biomechanical measurement yields information about the horse's response to rider actions and is beneficial when evaluating training techniques and rider performance.

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Manufactures' addresses

Excel, MS Excel, Microsoft Corporation, Redmond, WA
Futek® mini load cell, www.futek.com, USA
GOM player, www.gomlab.com
Matlab ®, The MathWorks Inc, Natick, Massachusetts, USA
Mustang 2200, Kagra AG, Fahrwangen, Switzerland
ProReflex ®, Qualysis, Gothenburg, Sweden

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