Comparison of tri-axial accelerations of distal limbs at the walk in horses with different head positions and different optical input.

Bo Tjerkstra

Supervisors: Yvette Nout-Lomas, Colorado State University

Wim Back, Utrecht University

Abstract

Introduction

A component of the neurological exam in horses includes walking the animal while elevating the head, which often exaggerates a subtle problem. This is caused by the different head-neck position, but also by the different optical input the horse receives when the head is elevated. Another way of changing the optical input is by blindfolding the horse. This is another common component of the neurological exam, mostly done for localization of suspected vestibular disease when the horse is no longer showing an obvious head tilt. The objective of this study is to investigate the gait pattern in horses using Inertial Measurement Units (IMUs; Gulf Coast Data Concepts LLC, Waveland, MS, USA). Our hypothesis is that elevating the head in a neurological exam can be replaced by blindfolding the horse.

Material and methods

For this study a randomized, two-way crossover design was used. Fourteen clinically sound horses from different breeds were used (age range, 4 to 17 years, body weight, 523.8 ± 38.7 kg, height at the withers, 1,56 ± 0.05 m). They underwent 2 experiments on 2 different days. In this study we used 7 IMUs that are composed of a triaxial accelerometers (±16g) , triaxial gyroscope (±2000°/sec), triaxial magnetometer (compass) and a thermometer. Each day all 14 horses walked a course that included walking a section with the head in a neutral position, the head in an elevated position and blindfolded. The acceleration data of all 3 axes ,the Ax-axis (cranio-caudal direction), the Ay-axis (dorso-ventral direction) and the Az-axis (medio-lateral direction), were extracted and opened in Gulf Coast Data Concept XLR8R (Waveland, MS, USA). Using simultaneously recorded videos, at least 5 but when possible 10 continuous strides were selected and exported to Microsoft Excel 2016. Individual steps were identified and selected for analysis. Data is presented as means (AVG) ± standard error of the mean (SEM). Repeated measures analysis of variance and paired t-tests were used to determine significance when comparing groups. Analyses were performed using software (IBM SPSS Statistics version 24, IBM, Armonk, NY).

Results

Changing head position and removing visual input through blindfolding significantly effects distal limb acceleration of the thoracic limbs in all directions ($p=0.000$), but only leads to small, non-significant, changes in accelerations of the distal pelvic limbs. For both the Ax (craniocaudal) and Az (mediolateral) directions there is no significant difference between distal thoracic limb accelerations while the horse is walked with the head elevated and while blindfolded. When evaluating repeatability of our measurements there were no significant differences between day 1 and day 2 during the walk with the head in a neutral position and with the head in an elevated position. However, when horses were blindfolded, thoracic distal limb accelerations were significantly reduced on day 2 when compared to day 1 in the Ax, Ay and Az directions ($p=0.021$, $p=0.001$ and $p=0.012$, respectively).

The minimum and maximum accelerations in the thoracic limbs are significantly affected by changing head position and removing visual input through blindfolding in all directions. We show that there are significant differences in the minimum and maximum distal thoracic limb acceleration during walking with the head elevated and walking blindfolded when compared to walking with the head in a neutral position ($p=0.000$). In the Ax (craniocaudal) direction there is no significant difference in the minimum and maximum distal thoracic limb acceleration between head elevated and blindfolded; however, in the Ay (dorsoventral) direction a significant difference was found in the maximum distal thoracic limb acceleration between head elevated and blindfolded animals ($p=0.001$). Furthermore a significant difference was found between day 1 and day 2 in the minimum and maximum distal thoracic limb

accelerations in the Ax (craniocaudal) direction of blindfolded horses ($p=0.033$ and $p=0.028$, respectively).

Video analyses showed a significant increase in observed abnormalities in run 1 compared to the last run in blindfolded horses. No significant differences were found between day 1 and day 2 in blindfolded or head-elevated horses.

Main limitations

The main limitations of this study include the outdoor environment, different handlers and different weather conditions. Also, the accelerometers were attached to the skin, not bone, which could also have resulted in artefacts due to skin displacement. Limitations for the video analyses include the dusty environment and the observations were made by only 1 person.

Conclusion

Results from this study show that in horses with a normal gait head elevation in a neurological exam can be substituted by blindfolding the horse when evaluating the Ax (craniocaudal) and the Az (mediolateral) direction. However, based on this study, the horse should be given some time to adjust to walking while blindfolded.

Introduction

To recognize and establish the severity of ataxia or lameness, veterinary clinicians need to critically assess abnormal gait patterns of horses that are not sound (1-3) To score ataxia, veterinarians use a grading scale from 0 (sound) to 5 (recumbent) (4,5). However, various studies suggest a poor agreement between clinicians, especially when clinical signs are mild (1). This is similar to what has been found in lameness examinations (2,3,6). Furthermore, some studies suggest that clinicians are prone to expectation bias in gait and lameness assessment (1,3). Subjective examination, thus, appears not to be very reliable and a more objective way of examination is necessary (3,6).

Various objective methods for gait analysis in horses have been investigated, for example kinetic analyses (7), kinematic analyses (8), accelerometers (9) and Inertial Measurement Units (IMUs) (10). In one study kinetic, kinematic and accelerometer analysis were performed simultaneously to evaluate gait in horses with xylazine-induced ataxia (11). In that study, Nout-Lomas et al. (2016) found that stride parameters determined by kinematic analyses were significantly different depending on dose of xylazine administered, which was consistent with data from Luining et al. (2016) who showed that thoracic distal limb acceleration were significantly higher in horses when they were walked with their heads in an elevated position when compared to when their heads were in a normal position. Furthermore it has been shown that head elevation with either flexion or extension at the poll causes a weight shift from the forehand to the hindquarters (13). Also stride length, overreach distance and suspension duration are affected by this change in head position, with the stride length and overreach distance decreasing and the suspension duration increasing when elevating the head (13). Gómez Alvarez et al. (2006) showed that an elevated head and neck position induced extension in the thoracic region and flexion in the lumbar region, reducing the sagittal range of motion.

A component of the neurological exam in horses includes walking the animal while elevating the head, which often exaggerates subtle neurological dysfunction (4). This is likely caused by an altered head-neck position, but also by a different optical input the horse receives when the head is elevated. In some horses, however, elevating the head can be difficult or painful. For example, they will refuse to walk with their head elevated or misbehave while walking with their head elevated. Also, elevating the head when walking tall horses can be difficult. Another way of changing the optical input is by blindfolding the horse. This is also frequently done in neurological examinations, mostly when clinicians are investigating a suspected vestibular disease (4).

Here, the aim is to investigate acceleration patterns of distal limbs of horses using IMUs with the goal of determining whether elevating the head during a neurological exam could be replaced by blindfolding the horse. We hypothesize that there would be a difference in thoracic and pelvic distal limb acceleration between walking with the head normal and the head elevated and between walking with the head normal and walking while blindfolded. We also hypothesize that there would be no difference in thoracic and pelvic distal limb acceleration between walking with the head elevated and walking while blindfolded.

Furthermore we investigated whether there was a difference in distal limb accelerations between recordings from day 1 and day 2. We hypothesized that there would be no difference in acceleration while walking with the head in a normal position between the first and second day, but we hypothesized that there would be a difference in acceleration while walking with the head elevated and while walking blindfolded between the first and the second day.

In addition, we analyzed videos taken during these recordings and evaluated the number of gait irregularities seen during these trials to determine whether there was a difference between the first run and the last run of both days and between the first and the second day. We hypothesized that there would be more irregular events noticed in the first run than the last run and that there would be more abnormalities in the first day than the second day.

Material & Methods

Experimental design

For this study a randomized, two-way crossover design was used. Fourteen clinically sound horses underwent 2 experiments on 2 different days (Low dose (LD) and High dose (HD)) with at least 5 days in between. Data were collected before (Control LD and Control HD) and after administration of xylazine (xylazine HCL, 0.2 mg/kg i.v. for LD and 0.7 mg/kg i.v. for HD). For this report only data collected before sedation were used.

This study was approved by the Colorado State University Institutional Animal Care And Use Committee (Protocol # 16-6585AA)

Horses and Instrumentation

Fourteen clinically sound horses from different breeds were used (age range, 4 to 17 years, body weight, 523.8 ± 38.7 kg, height at the withers, 1,56 ± 0.05 m). We used 7 Inertial Measurement Units (IMUs) (Gulf Coast Data Concepts LLC, Waveland, MS, USA; Figure 1) that are composed of a triaxial accelerometer (±16g) , triaxial gyroscope (±2000°/sec) and triaxial magnetometer (compass). The accelerometers were set to record at 100 Hz. IMUs were turned on and were laid down on the ground for calibration purposes, after which they were attached with tape or Velcro to the lateral aspect of the distal cannon bones on each leg, the sacrum and the two tuber coxae. For IMU placement on the cannon bones, the left front IMU was placed 4 cm proximal to the fetlock joint and the other 3 were placed on the other limbs at the same height as that left front one, measured from the ground (Figure 2). The IMUs were placed on the dorsal aspect of the tuber coxae and using a level the X-axis was aligned to lie in the vertical plane (Figure 3). When the devices were attached, they were briefly tapped with fingers so the IMU data from all devices could be matched after data collection. The IMUs on the distal limbs were placed so the Ax-axis corresponded with the cranio-caudal direction, the Ay-axis corresponded with the dorso-ventral direction and the Az-axis corresponded with the medio-lateral direction. This report concerns data recorded from the distal limbs; we will not be reporting on data collected from the sacrum or tuber coxae.

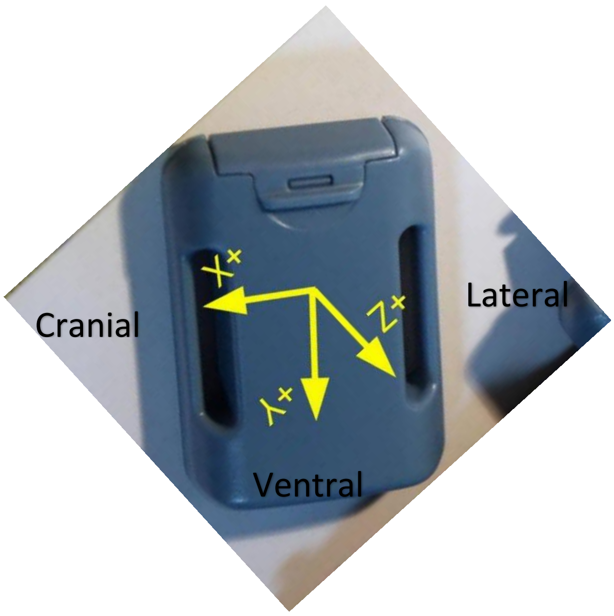

Figure 1. Inertial Measurement Units (IMUs) with the orientation of the 3 axis illustrated.

Figure 2. IMU placement on the cannon bones. The Left Front IMU was placed 4 cm proximal to the fetlock joint and the other three were placed on the other limbs at the same height as that Left Front one, measured from the ground.

Figure 3. IMU placement on the sacrum and tuber coxae. The IMUs were placed on the dorsal aspect of the tuber coxae and using a level the X-axis was aligned to lie in the vertical plane.

IMU data collection protocol

The protocol for data collection was as follows (Figure 4): Horses were walked along a pathway with 4 ground poles followed by 4 cavalettis with a distance of 2 meters in between (exercise 1). This was repeated 3-5 times. The horses then were blindfolded and walked in a straight line for 30 meters with their head in a normal position (exercise 2). This was either done for 2-6 times or until there were at least 2 runs with 5 to 10 continuous strides. Subsequently the blindfold was taken off and the horses were walked in a straight line for 30 meters with their head in a normal position (exercise 3). They were then turned around and walked for 30 meters with their head elevated (exercise 4). Next, they walked 3 circles to the left (exercise 5) followed by 3 circles to the right (exercise 6). They were then walked in a straight line for 30 meters with their head in a normal position (exercise 7), followed by walking in a straight line for 30 meters with their head elevated (exercise 8). After this, the horses were sedated with xylazine HCL, 0.2 mg/kg i.v. for LD or 0.7 mg/kg i.v. for HD. Five minutes after administration of the sedative the horses were put through exercises 3-8 again (Figure 4).

To facilitate differentiation of separate runs in the raw data files, horses were stopped for 2-3 seconds before and after they moved from one exercise to the next. During data collection, notes were made about any abnormal events, for example spooking, defecating, sounds, weather circumstances and other distractions. All the experiments were videotaped for possible later review.

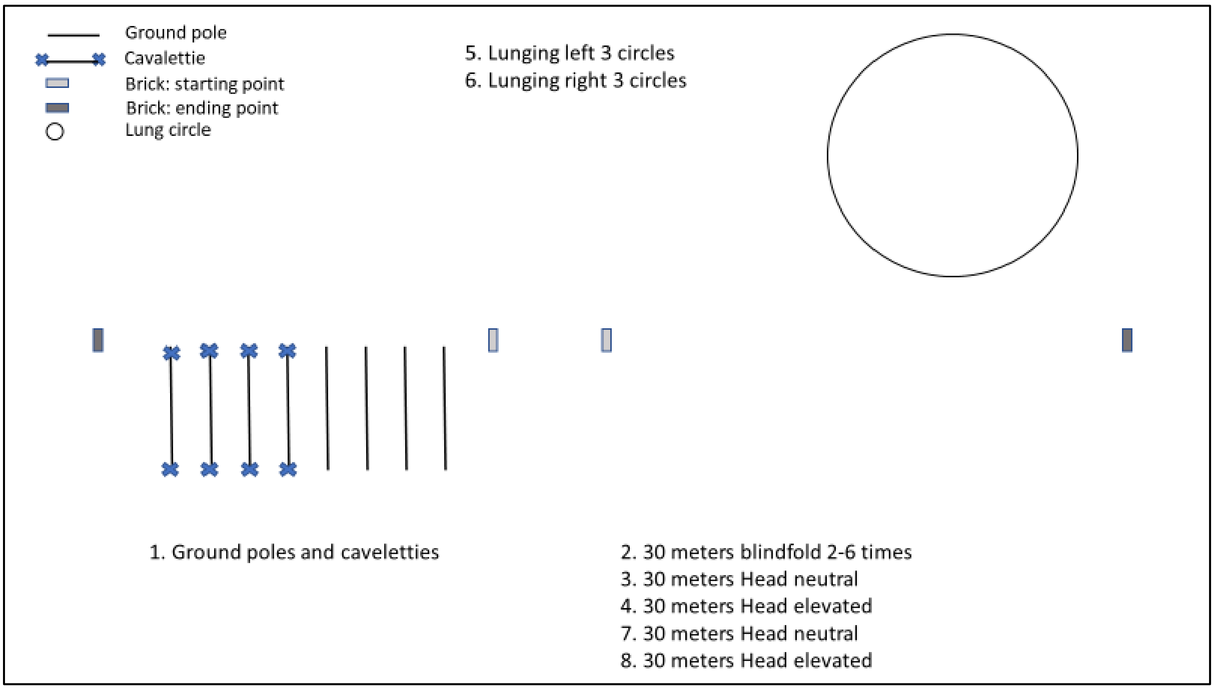

Figure 4. IMU data collection protocol. Graphical representation of the sequence of the data collection protocol.

Video analysis

All head normal, head elevated and blindfolded videos were analyzed and for each stride notes were made if there were any abnormalities seen. Abnormalities recorded and quantified while evaluating horses that were walked blindfolded were: 1) standing still: horse stops and is no longer moving forwards, 2) walking sideways: horse is not following a straight path but is shifting laterally with the thoracic or pelvic limbs, 3) lifting its feet up high: the position of the carpi/tarsi was higher compared to the videos of the horses walking a 30 meters straight line with their head in a normal position and 4) searching with its feet: slow lifting of the hoof, frequently high and careful placement of the hoof on the ground. For quantifying abnormalities while evaluating horses walking with their head elevated 2 more abnormalities were added: 5) dragging their feet: no space seen between the ground and the feet while making a stride and 6) making shorter strides: the pelvic limbs did not step in the print left by the thoracic limbs. This was done for the thoracic limbs and the pelvic limbs separately.

Data analysis

<u>IMU data collection</u>

Data were downloaded from the IMUs to a computer and opened in Microsoft Excel 2016. Only the data of the straight lines of 30 meters with the blindfold, normal head position and head elevated position of the 4 IMUs on the canon bones were used for this analysis. The files were split in Excel to obtain a separate blindfold and walking file. The acceleration data were extracted and saved in a separate blindfold accelerations or walk accelerations file and opened in Gulf Coast Data Concept XLR8R (Waveland, MS, USA). With help of the video recorded experiments at least 5 but when possible 10 continuous strides were selected and exported to Microsoft Excel 2016. Individual steps were identified and selected to a separate page in the same file (Figure 5).

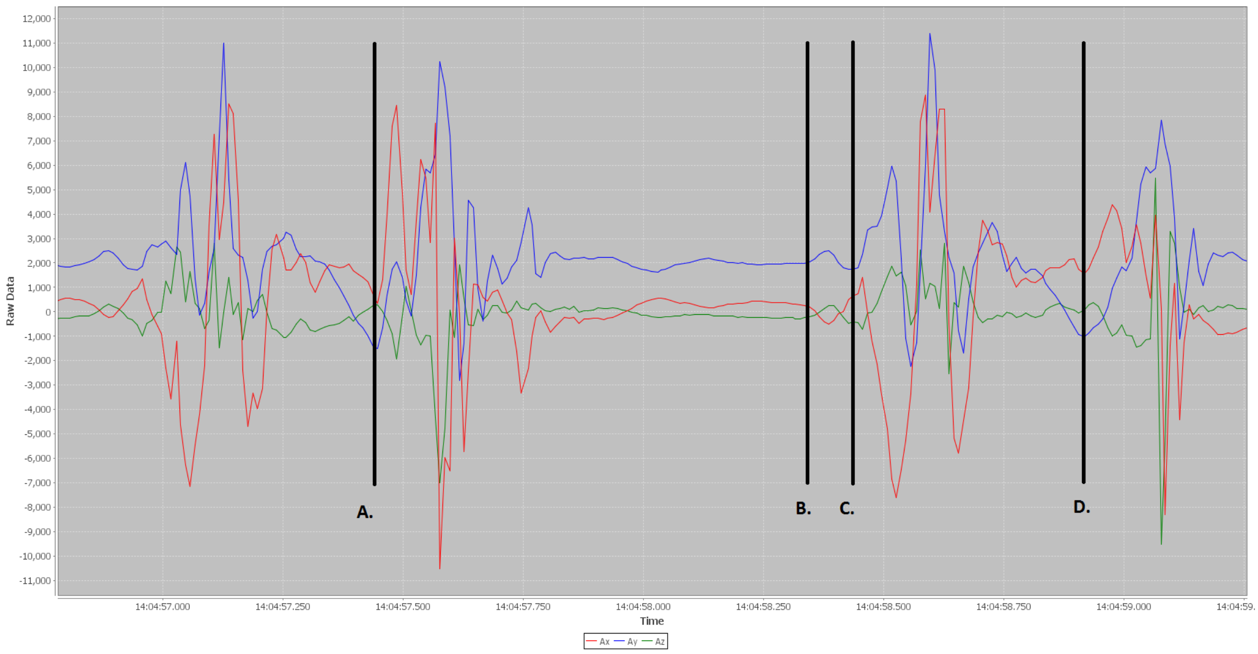

Figure 5. Example of an individual step of the left thoracic limb of horse 2 with a normal head position. A: heel and toe down, B: heel off, C: toe off and D: heel and toe down. The Ax (craniocaudal) direction is represented by the red line, the Ay (dorsoventral) direction is represented by the blue line and the Az (mediolateral) direction is represented by the green line.

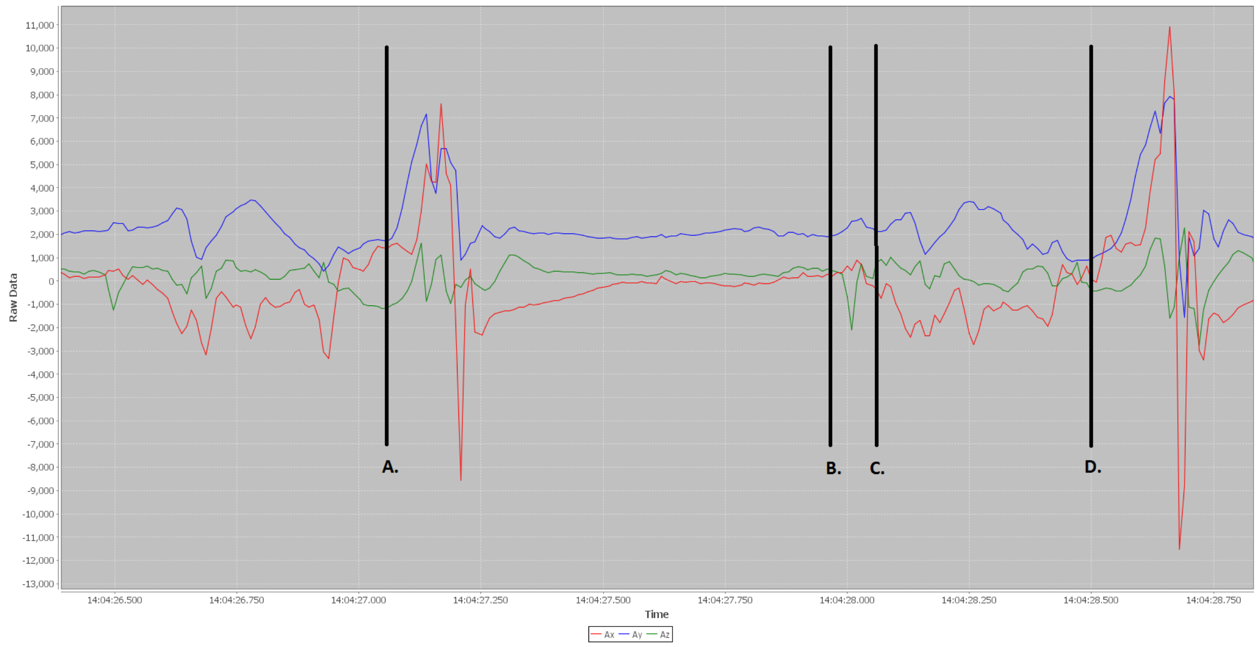

Figure 6. Example of an individual step of the left pelvic limb of horse 2 with a normal head position. A: heel and toe down, B: heel off, C: toe off and D: heel and toe down. The Ax (craniocaudal) direction is represented by the red line, the Ay (dorsoventral) direction is represented by the blue line and the Az (mediolateral) direction is represented by the green line.

<u>Calculations</u>

The Ax, Ay and Az-axis data were converted from the raw data to g-forces using the mathematical formula 1 g equals 2048 counts. Then, the minimal value, maximal value, range and mean of each step of each leg with each head position (Head normal, Head elevated and Blindfold) of the Ctrl LD and Ctrl HD for the Ax, Ay and Az-axis were determined.

Subsequently, the mean of the range, standard error and standard deviation were determined of each horse of the thoracic limbs and pelvic limbs for the first day, second day and both days of the experiment for each head position (Head normal, Head elevated and Blindfold) in the Ax, Ay and Az-axis.

Also, the mean of the minimum and maximum values, standard error and standard deviation were determined of the thoracic limbs for the first day, second day and both days of the experiment for each head position (Head normal, Head elevated and Blindfold) in the Ax and Ay-axis.

To compare variability from run to run and day to day, mean values from each horse for each run or day were used.

Video analysis

Only the abnormalities in the first and last run of day 1 and day 2 were used in this data analysis. Every abnormality in the thoracic and pelvic limbs in the first and last run of each day in the blindfold and head elevated runs were registered for each stride made. Either the abnormality was present or it was not; no differentiation in severity of abnormalities were made. Ten strides from step 5 to 22 were picked, mostly step 5 to 14, and all abnormalities of the thoracic and pelvic limbs that occurred during these 10 steps were tallied. The abnormalities from the first and last run were added up to make a total of abnormalities of each day for each horse, so day 1 and day 2 could be compared.

Manual vs Matlab

Seven scripts were written in Matlab (Mathworks, Natick, MA, USA) for automatic analysis of IMU data (15). Raw IMU data of 3 horses in the Ax-axis were analyzed using these custom-built Matlab scripts and the output (acceleration range) was compared to that obtained using the method described above, also referred to as the manual analysis.

Statistical analysis

Data is presented as means (AVG) ± standard error of the mean (SEM). Repeated measures analysis of variance was used to compare the effects of head position and visual input on distal limb acceleration. Paired t-tests were used to compare effects of run (first and last run) and day (day 1 or day 2) of data recording. Analyses were performed using software (IBM SPSS Statistics version 24, IBM, Armonk, NY).

Results

All horses successfully completed the experiments. One data point was not recorded: for Horse 8, the right pelvic limb IMU failed to record data during the Control HD experiment while the horse was walking over groundpoles/cavalettis and walking while blindfolded.

Range of distal limb accelerations

<u>Effect of head position and visual input on range of distal limb accelerations</u>

Changing head position and removing visual input through blindfolding significantly effects acceleration of the distal thoracic limbs in all directions ($p=0.000$), but only leads to small, non-significant, changes in accelerations of the distal pelvic limbs (Figure 1). Distal thoracic limb accelerations are significantly increased during walking with the head elevated and during blindfolded walking when compared to walking with the head held in a neutral position. For both the Ax (craniocaudal) and Az (mediolateral) directions there is no difference noted between distal thoracic limb accelerations while the horse is walked with the head held elevated and while blindfolded. However, in the Ay (dorsoventral) direction distal thoracic limb acceleration is smallest when the head is held neutral, and this difference is significant between head neutral and head elevated ($p=0.000$) and between head neutral and blindfolding ($p=0.012$). Furthermore, distal thoracic limb acceleration is greatest while the head is elevated, and this difference is significant between head neutral and head elevated ($p=0.000$) and between blindfolding and head elevated ($p=0.003$).

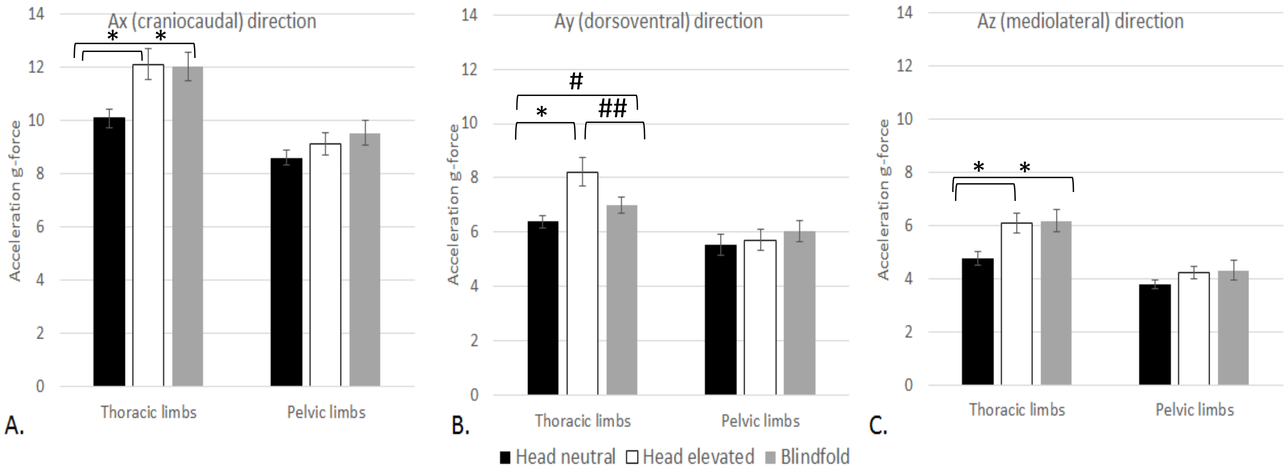

Figure 7. The effect of head position and blindfolding on the range of thoracic and pelvic limb acceleration in Ax, Ay and Az directions (n=14). A: Ax (craniocaudal) direction , B: Ay (dorsoventral) direction, C: Az (mediolateral) direction

*p=0.000; #p=0.012; ##p=0.003

<u>Day to day repeatability of measures</u>

When evaluating repeatability of our measurement there were no statistically significant differences found between day 1 and day 2 accelerations from the distal thoracic limbs during the walk with the head in a neutral position (Figure 2A) and with the head in an elevated position (Figure 2B). However, when horses were blindfolded, thoracic distal limb accelerations were significantly reduced on day 2 when compared to day 1 in the Ax, Ay and Az directions (p=0.021, p=0.001 and p=0.012, respectively). No significant differences were found in accelerations recorded from the pelvic limbs when day 1 and day 2 recordings were compared.

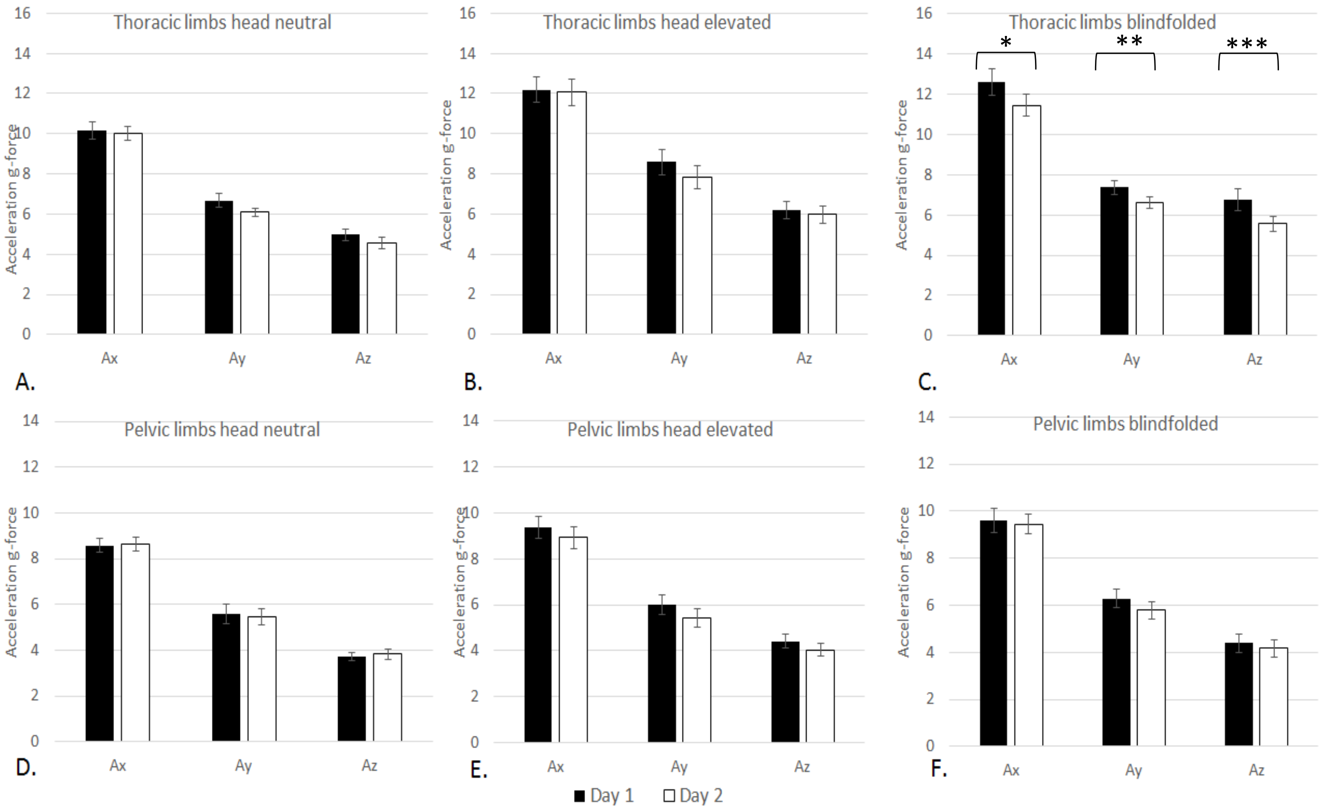

Figure 8. The effect of different days on the range of thoracic and pelvic limb accelerations with different head positions and blindfolding in Ax, Ay and Az directions (n=14). A: Recordings from thoracic limbs with a neutral head position, B: Recordings from thoracic limbs with an elevated head position, C: Recordings from thoracic limbs with blindfold, D: Recordings from pelvic limbs with a neutral head position, E: Recordings from pelvic limbs with an elevated head position, F: Recordings from pelvic limbs with blindfold

* p=0.021; ** p=0.001; *** p=0.012

Minimum and Maximum accelerations

Effect of head position and visual input on the minimum and maximum distal thoracic limb accelerations

The minimum and maximum accelerations in the thoracic limb accelerations are significantly affected by changing head position and removing visual input through blindfolding in the Ax and Ay directions (Figure 3). In the Ax (craniocaudal) direction the minimum distal thoracic acceleration is significantly less and the maximum distal thoracic limb accelerations is significantly increased during walking with the head elevated and walking blindfolded when compared to walking with the head in a neutral position (p=0.000). There is no significant difference between walking with the head elevated and walking blindfolded in the Ax (craniocaudal) direction in both minimum and maximum distal thoracic limb accelerations (Figure 3A). In the Ay (dorsoventral) direction there is a significant difference in minimum distal thoracic limb accelerations recorded when the head is elevated when compared to head neutral and when compared to blindfolding (p=0.000). Maximum distal thoracic limb accelerations in the Ay directions were significantly different between the 3 groups with the largest accelerations recorded while the head was elevated (p=0.000).

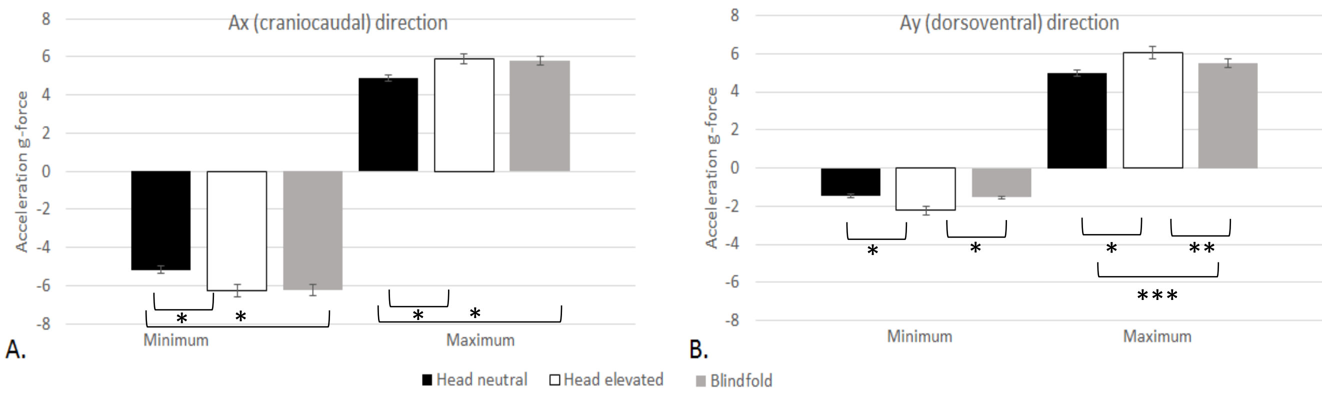

Figure 9. The effect of head position and blindfolding on the minimum and maximum accelerations of the distal thoracic limb in Ax and Ay directions (n=14). A: Ax (craniocaudal) direction , B: Ay (dorsoventral) direction

* p=0.000; ** p=0.002; *** p=0.005

Day to day repeatability of measures

When evaluating the minimum and maximum distal thoracic limb acceleration, recorded while horses were walked with their head in neutral position and in the elevated position, there were no significant differences between day 1 and day 2 in the Ax (craniocaudal) and Ay (dorsoventral) directions. However, when horses were blindfolded significant differences were found in distal thoracic limb acceleration in both the Ax (craniocaudal) and Ay (dorsoventral) directions. In the Ax direction, both the minimum and maximum distal thoracic limb accelerations significantly decreased (p=0.033 and p=0.028, respectively) on day 2 compared to the day 1. In the Ay direction, only the maximum distal thoracic limb acceleration significantly decreased (p=0.001) in blindfolded animals (Figure 4).

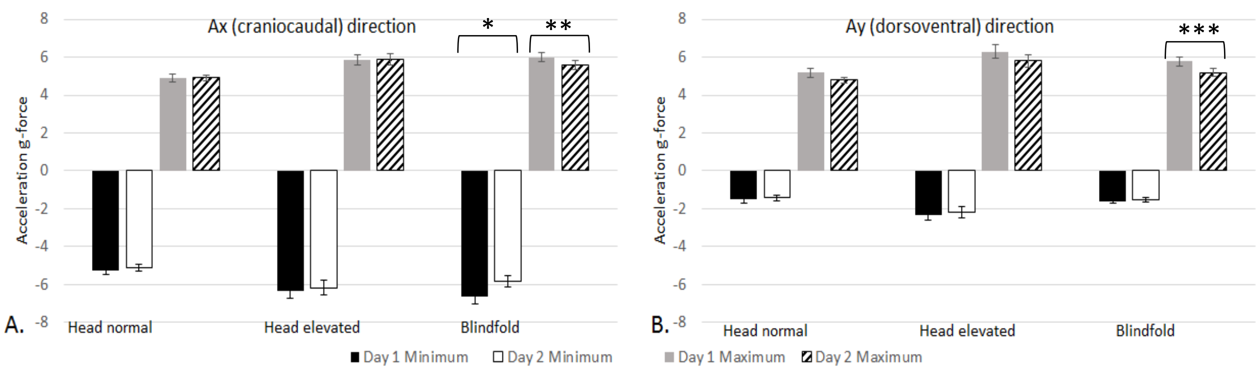

Figure 10. The effect of different days on the minimum and maximum accelerations of the distal thoracic limbs with different head positions and blindfolding in Ax and Ay directions (n=14). A: Ac (craniocaudal) direction, B: Ay (dorsoventral) direction

* p=0.033; ** p= 0.028; *** p=0.001

Video analysis

Run to run and day to day repeatability of measures

While assessing the variability of results between the first and last runs of the same day and between results from day 1 compared to day 2 from video analyses, no significant differences were found with regard to detectable errors made by the horses while they were walked with their heads elevated (Figure 5).

Observed abnormalities in horses with an elevated head position														
	Horse 1	Horse 2	Horse 3	Horse 4	Horse 5	Horse 6	Horse 7	Horse 8	Horse 9	Horse 10	Horse 11	Horse 12	Horse 13	Horse 14
Day 1														
Run 1	13	1	0	0	10	12	0	0	1	10	12	1	0	0
Last run	7	6	19	4	10	0	0	0	3	8	10	0	0	0
Total	20	7	19	4	20	12	0	0	4	18	22	1	0	0
Day 2														
Run 1	8	0	0	8	9	0	0	1	2	10	8	0	0	0
Last run	17	0	0	4	3	6	0	0	1	5	1	0	0	0
Total	26	0	0	12	12	6	0	1	3	15	9	0	0	0
		Run 1 has more abnormalities than the last run												
		Day 1 has more abnormalities than day 2												

Figure 11. The effect of different runs and different days on observed abnormalities in horses with an elevated head position (n=14)

However, we did find a significantly increased number of detectable errors made in blindfolded horses during the first run when compared to the last run ($p=0.005$) (Figure 6).

Observed abnormalities in blindfolded horses														
	Horse 1	Horse 2	Horse 3	Horse 4	Horse 5	Horse 6	Horse 7	Horse 8	Horse 9	Horse 10	Horse 11	Horse 12	Horse 13	Horse 14
Day 1														
Run 1	10	25	5	0	0	9	0	4	11	2	13	18	0	2
Last run	7	7	1	0	2	2	3	1	5	0	10	2	0	0
Total	17	32	6	0	2	11	3	5	16	2	23	20	0	2
Day 2														
Run 1	10	3	0	10	4	10	0	6	0	0	10	0	1	2
Last run	0	0	0	10	2	0	0	2	0	0	4	0	0	0
Total	10	3	0	20	6	10	0	8	0	0	14	0	1	2
		Run 1 has more abnormalities than the last run												
		Day 1 has more abnormalities than day 2												

Figure 12. The effect of different runs and different days on observed abnormalities in blindfolded horses (n=14).

Matlab versus Manual data

Range of distal limb accelerations in Ax (craniocaudal) direction

While comparing the distal limb accelerations analyzed by an IMU data processing program developed in Matlab to the method used above by evaluating data from 3 horses in Ax (craniocaudal) direction there were no significant differences found.

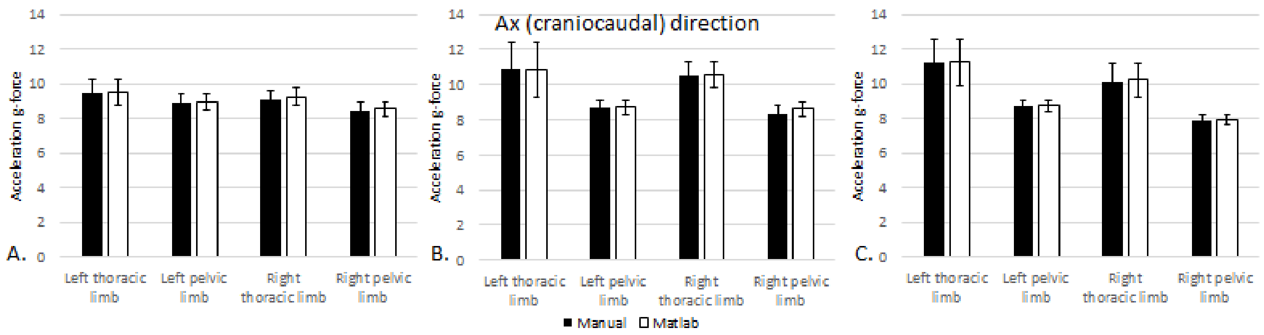

Figure 13. Verifying Matlab IMU data processing program in horses with different head positions and while blindfolded in Ax (craniocaudal) direction (n=3). A: Neutral head position, B: Elevated head position, C: Blindfolded

Discussion

Here we show that changing head position and removing visual input leads to significant changes in accelerations of the distal thoracic limbs in horses. Both walking with the head elevated and walking while blindfolded leads to a significantly increased distal thoracic limb acceleration when compared to walking with the head in a neutral position. Previous studies have shown that elevating the head results in shorter and faster strides with a reduced stance phase (11,12). However, to the best of our knowledge, this is the second study in which it is shown that this is accompanied by increased acceleration of the distal limb. Furthermore, this is the second study showing that changes in distal limb acceleration with head elevation are similar to what is seen when horses are blindfolded. Our data shows that there are no significant differences in distal limb accelerations in both the Ax (craniocaudal) and Az (mediolateral) directions when horses are walked with the head elevated or walked while blindfolded. This suggests that in a neurological examination head elevation could be substituted by blindfolding. However, if the evaluator is interested in acceleration in the Ay (dorsoventral) direction these exercises cannot be considered the same, since in this study we show that distal thoracic limb acceleration in the Ay (dorsoventral) direction is significantly higher in horses with an elevated head position than in blindfolded horses. Indeed, we found that also the minimum and maximum distal thoracic limb accelerations are significantly lower and higher, (respectively), in the head elevated group when compared to blindfolded group. An explanation for this could be that blindfolded horses are more careful putting their feet down, because of the complete lack of visual input. This is also suggested by what was seen in the videos and shown by the measured irregularities.

Elevating the head in the neurological examination in horses is done to exaggerate any subtle problems and provide the evaluator with a better insight of the presence of mild ataxia. We suspect exaggeration of clinical signs is caused by the different head-neck position, but also because of the different optical input the horse receives when the head is elevated (4). However, not all horses will elevate their head easily. Some horses are painful while elevating their head and will therefore refuse to walk or misbehave with their head in this position and in some horses, especially tall ones, elevating the head is difficult. Our data suggest that substituting head elevation with another way of changing optical input, for example blindfolding, could be a solution to some of these problems. In both elevating the head and blindfolding the main principle is the same which is to change the visual input to reveal any mild ataxia. The neurological examination is familiar with blindfolding horses, since this is commonly used to localize suspected vestibular disease, in particular, when the horse is not showing an obvious head tilt (4).

When comparing data between day 1 and day 2 we did not find significant differences in distal thoracic limb accelerations in horses with neutral and elevated head position, however, we did find that in blindfolded horses distal thoracic limb accelerations are reduced on day 2 when compared to day 1. We hypothesize that blindfolding, where vision is completely removed, is a more significant change for the horse when compared to elevating the head which still allows some vision. In horses that are not familiar with walking blindfolded, this exercise results in exaggerated lifting of feet followed by careful placement of feet, which is much more prominent on day 1 compared to day 2. These findings are supported by our video analyses. In head-elevated horses there are no significant differences in the amount of observed abnormalities when comparing the first to the last run and the first to the second day, but in blindfolded horses there is a significant decrease in observed irregularities when comparing the first to the last run. However, video analyses do not show a significant difference between the first and the second day which indicate that recording accelerations is more sensitive to this finding than video-recorded irregularities are. This is the first study measuring distal limb accelerations in blindfolded horses, so more research should be done to explain this more thoroughly.

Our data do not show significant differences in pelvic limb accelerations during these exercises. This difference in effect of head position and blindfolding on thoracic vs. pelvic limb accelerations could be explained by the different roles in locomotion they have. Pourcelot et al. (1997) show a higher symmetry in thoracic limb movements when compared to pelvic limb movements. They hypothesize this is explained by the propulsive role of the pelvic limbs as opposed to the supporting role of the thoracic limbs. Adding to this theory is Oosterlinck et al. (2011) who show a lower and more variable pelvic limb loading than thoracic limb loading in ponies, which also is suggested to be a consequence of the different roles these limbs play in locomotion. We suggest that the different functions of the thoracic vs. pelvic limbs also likely explain the difference we find in this study when comparing head elevation and blindfolding to walking with a head held in neutral position in these limbs.

In this study, we used accelerations recorded by IMUs as a more objective measurements of gaits. As mentioned before, various studies suggest that there is poor agreement between clinicians, especially when clinical signs are mild (1). Subjective examinations are not very reliable and more objective measurements are necessary (3,6). IMU's are relatively new in gait analysis and especially in horses with ataxia. So far IMU's have only be used in horses to asses lameness, symmetry and validation of the IMU itself (3,10,18,19), no research has been done with IMU's in ataxic horses. The same can be said for evaluation of specifically distal limb acceleration , Nout-Lomas et al. (2016) and Luining et al. (2016) have used accelerometers to study xylazine-induced and clinically ataxic horses. There is very little data to compare our results to, which is one of the limitations of this study.

Other limitations of this study include the outdoor environment and different handlers. The outdoor environment and variable handlers lead to slightly different conditions during data collection. Different weather conditions and a different way of handling the horse can lead to different reactions and different behavior of the horses, leading to different distal limb accelerations. Furthermore, the dirt surface may have resulted in artifacts due to the extra vibrations caused by horses dragging their toes and not picking up their feet correctly. Also, the dust made it more difficult to identify abnormalities in the video analysis. Additionally, the IMUs were attached to the skin, not bone, which could also have resulted in artefacts due to skin displacement. Another limitation in the video analysis was that observations were made by one person.

In summary, we show that in horses with a normal gait head elevation in a neurological exam can be substituted by blindfolding the horse when evaluating the Ax (craniocaudal) and the Az (mediolateral) direction. However, based on this study, the horse should be given some time to adjust to walking while blindfolded. Further research is warranted to determine whether these results can be extrapolated to ataxic horses and to analyze more precisely how long the adjusting time to blindfolding is. This could give us more insight in whether head elevation can be substituted by blindfolding in ataxic horses, which are the target population in a neurological exam.

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