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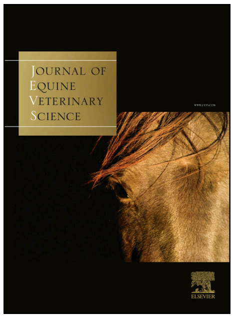

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Local back pressure caused by a training roller during lunging with and without a Pessoa training aid

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Abstract

Reasons for performing the study: Ground schooling (especially lunging) is routinely performed in the rehabilitation and training of horses. Training rollers are commonly used to provide attachment for training aids. *Objectives:* To objectively measure pressures beneath a training roller during lunging exercise with and without a Pessoa training aid. *Methods:* To measure pressures underneath the roller; ten non-lame horses (mean±SD age 12±8.77 years, mean±SD height 1.65±0.94m) were lunged on a sixteen metre circle wearing a training roller on top of a high withered dressage square and wool pad. A Pliance (Novel) pressure mat was positioned transversely over the spinous processes covering thoracic vertebrae ten to fifteen. Data were collected in both trot and canter on left and right reins, with and without a Pessoa training aid. For pelvic range of motion (ROM), horses were instrumented with five inertial measuring units sensors (IMU). A paired T-test was used to determine differences in pressure and pelvic ROM with/without Pessoa training aid ($P \leq 0.05$). *Results:* In trot and canter consistent high pressures on the spinous processes beneath the roller were greater than those thought to cause back discomfort. These pressures were consistent between horses. No significant differences were found in any IMU outcome parameters. *Conclusion:* Awareness of the increased local spinal pressure a training roller exerts on the back, especially in horses undergoing rehabilitation of back problems.

Keywords

horse, locomotion, roller, Pessoa, lunging, pressure

1. Introduction

Back pain and dysfunction in the ridden horse are common causes for poor performance with horse owners (1-4), therapists, trainers and veterinarians working together to develop strategies to aid in the treatment and prevention of back pain and dysfunction. Studies in man have shown the importance of optimal musculature system in the protection against injury, as well as the use of specific exercises to stimulate deep stabilising muscles *multifidi*, to help improve core musculature and in doing so providing resolution of back pain (5, 6) . A similar trend has been shown in the horse where improving core muscle strength can provide stability to the vertebral column (7, 8). In cases of back pain and dysfunction, these muscles can become dormant and atrophied thus compromising the locomotor system and heightening the chances of back dysfunction (8).

In an attempt to condition the horse's musculature and provide variety to exercise regimes, horse owners use ground schooling - most commonly in the form of lunging with a training aid - as a form of exercise. It has been reported that the overall force acting on the horse's back whilst trotting with a rider is equivalent to two times the body mass of the rider (9). Therefore, it seems likely that when lunging, and by removing the weight of the saddle/rider, the locomotor system and musculature can be influenced in a different manner.

Training aids are regularly used as supplementary equipment whilst lunging. Several training aids are available. Although limited, a study has shown that the Pessoa training aid has an effect on whole horse locomotion, where a reduction in speed, stride length, head angle, and lumbosacral angle (at maximal hind limb protraction) were reported (10). Although differences were reported, no increase in the loading of forelimb and hindlimb structures were found (10). Resistance created by the positioning of elastic resistant bands around the horse's hind quarters and abdominals, has received scientific attention where it was found that increased stability of the vertebral column was achieved (7). Training aids generally require the addition of a training roller, allowing for attachments to be made from the training aid to the bit/horse. Unlike saddles, bridles and girths, where there have been advances with scientific information (11-15), to the authors' knowledge there have been no studies looking at the effect that a roller has on the horse.

The aims of this study were to investigate the pressure distribution beneath a roller when fitted with and without a Pessoa training aid, to identify if there is an increase in pressure beneath the roller when using a Pessoa training aid and to investigate its effect on pelvic ROM.

The objectives of this study were to quantify: 1) the pressure distribution beneath a roller when fitted with and without a Pessoa training aid; 2) quantify differences in pelvic ROM when fitted with and without a Pessoa training aid.

It is hypothesised that there will be: 1) repeatable high pressures beneath the roller, directly on the spinous process in the region of the eleventh and twelve thoracic vertebra; 2) an increase in high pressures beneath the roller when being used with a Pessoa training aid; 3) smaller pelvic ROM as a result of the high pressures beneath the roller.

2. Materials and Methods

The study was approved by the ethics and welfare committee of the first author's institution, project number URN 20131238.

2. Effect of rollers on pressure distribution and locomotion.

2.1 Horses

A convenience sample of ten adult sports horses (mean±SD age 12±8 years, height 1.65±0.09m) were used. Horses and riders were recruited via Facebook asking for volunteers to participate in this study. Inclusion criteria were that horses were in regular competitive work preceding the study and were deemed fit and sound by their riders. Horses were assessed by the volunteers' own veterinarian the day preceding the study. Informed consent was obtained and riders could withdraw from the study at any point should they wish to do so. All horses were housed at the same facility for mean±SD 10±2 years. As part of the normal work routine all horses engaged with lunge exercise at least once a week using a Pessoa training aid, therefore all horses were suitably acclimatised to lunging and the attachment of training aids. All horses were warmbloods and of a similar conformation, all competing at affiliated dressage (elementary – advanced medium) and displaying good muscle definition with a well-defined musculature of the thoracolumbar region.

2.2 Lunging protocol

A non-anatomically shaped headpiece with a snaffle bit was used for all horses. A standard lunging cavesson was used over the top of the headpiece. The noseband had three rings, one of which was located on the midline and another located on each side (left and right), regardless of direction of travel, the middle ring was used throughout. Horses were lunged on a sixteen metre circle, a standard lunging line was used which had marker paint on it representing the required distance for lunging.

2.3 Roller

A web roller designed to fit all horses was used for the study. The roller had a non-rigid gullet, created by two triangular pads filled with foam on the underside of the roller. The roller was made from 100% Polypropylene, ten centimetres (cm) wide and could be adjusted so that its shortest length was 192 cm long and its longest length was 225 cm. The roller was equipped with twelve rings (2" diameter). Rings were positioned on both sides of the roller allowing for the attachment of training aids. Rings were attached by webbing in the following places: 1) dorsal aspect, three rings were cranially, centrally and caudally positioned directly above the spine; 2) on the lateral aspect of the roller in line with the proximal edge of the scapular, one ring was positioned in line with ventral aspect of the scapular; 3) two rings were positioned mid scapular; 4) two rings were positioned in line with the proximal portion of the humerus. A non-anatomically shaped girth was used for the study which had a further ring positioned on the ventral aspect of the girth overlaying the sternum.

The roller was positioned in the region of thoracic eleven and twelve which corresponded in all horses with the line of the girth groove. One single technician, with over thirty five years' experience, palpated cranially from the lumbosacral junction identifying thoracic eleven and twelve; once identified, skin paint was applied. Between each trial, roller positioning was checked.

Beneath the roller was a wool roller pad on top of a high withered dressage square which was used throughout the study. The same Pessoa training aid was used and fitted following manufacturer's guidelines. It was adjusted to each horse based on horse height and horse length, ensuring that, when fitted, the horse's nose was on the vertical. The Pessoa training aid was attached to the snaffle for all horses. The middle ring (mid scapular) of the roller was used throughout for the attachment of the Pessoa to the bit and the roller.

2.4 Kinematics - Inertial Measurement Units

Horses were instrumented with five MTw inertial measurement units (IMU) (Xsens[a]). These were attached over the withers, sacrum and left tuber coxa (LTC) and right tuber coxae (RTC) using custom built pouches and double-sided tape. Sensor data were collected at 80 Hz per individual sensor channel and transmitted via proprietary wireless data transmission protocol (Xsens), to a receiver station (Awinda, Xsens) connected to a laptop computer running MTManager (Xsens) software.

IMU data were processed following published protocol (16) . In brief, tri-axial sensor acceleration data were rotated into a gravity (z: vertical) and horse-based (x: craniocaudal and y: mediolateral) reference frame and double integrated to displacement. Displacement data were segmented into individual strides based on vertical velocity of the sacrum sensor (17) and median values for the following kinematic variables were calculated over all strides for each exercise condition.

- range of motion: maximum – minimum value over a stride cycle for x, y and z for trot and canter
- minimum difference (MinD): difference between the two minima in vertical (z) displacement observed during the two diagonal stance phases in trot (18)
- maximum difference (MaxD): difference between the two maxima in vertical (z) displacement observed after the two diagonal stance phases in trot (18)
- tuber coxae difference (TCD): difference between vertical movement amplitude of left and right tuber coxae.

Due to the lack of direct speed measurements, stride time (from IMU data) was used as a surrogate measure making use of the relationship between speed and stride time within a gait (7).

2.5 Kinetic Data – pressure distribution

Kinetic data under the roller were recorded using a pressure mapping system[b] (Pliance System, Novel, MSA600, sampling rate 50 Hz). The pressure mat was positioned transversely over the back directly on the horse's skin. The pressure mat consists of 256 sensors arranged into 8 columns and 16 rows, although, given that the mat was positioned transversely and only the region where the roller was to be positioned was of interest, only 128 cells were active. The roller was positioned in the region of the eleventh and twelve thoracic vertebrae; the depth of the roller corresponded to row C (cranial edge) to E (caudal edge) on the pressure mat and cells seven, eight, nine and ten corresponded to width of pressure left-right with cell eight and nine being positioned on the midline; between each measurement the pressure mat was evaluated to check that it had not displaced laterally or cranial/caudally. For each horse, prior to measuring, the pad was zeroed without the roller or girth (19) this method has previously been described in relation to saddles (15). Peak pressures (kPa) in trot and canter for both conditions were collected.

2.6 Study Protocol

Each horse underwent a ten minute warm up period on the lunge without the roller or Pessoa training aid being attached. Spherical cones positioned at seventeen metres diameter marked the circumference of the circle in which trot and canter locomotion with and without the Pessoa training aid were measured. All measurements were performed on the same outdoor sand and rubber surface, which was groomed prior to and in between each trial (Logic, single blade leveler). All horses were handled and lunged by the same handler: female, 58 years, 5'2 height. A crossover design was carried out, with each horse lunging on the left and right rein in trot and canter for both conditions, the order of which was randomised. If the horse lost regularity, tripped or made an obvious alteration in gait pattern or circle size the trial was repeated. For two horses, circle size altered so the trial was aborted and repeated.

From IMU and pressure distribution, data were matched in relation to movement condition and data were collected from forty consecutive strides totaling mean 40±3 being used for analysis, in trot and canter on both left and right circles for each horse. This was repeated for both conditions, with and without a Pessoa training aid.

2.7 Statistical Analysis

Statistical analysis was performed in SPSS (vers. 22, IBM, Armonk, USA). Kinetic and kinematic outcome parameters were assessed for normality using a Shapiro Wilks Test and found to be normally distributed. Differences in outcome parameters for IMU and pressure data with and without a training aid in both trot and canter were assessed using a paired T-test with a significance level set at $P \leq 0.05$.

3. Results

3.1 Speed

Since many kinematic parameters are influenced by speed, we tested for differences in speed between different training aid conditions. Using a paired T-test with a significance level set at $P \leq 0.05$ no significant differences were found in stride time between the two conditions for any of the 4 combinations of gait (trot/canter) and movement direction (left/right rein direction): trot left rein, with training aid 724.71±52.49ms, without training aid 730.86±49.71ms, P=0.85), trot right rein, with training aid 730.00±50.43ms, without training aid 728.43±50.73ms, P=0.81), canter left rein, with training aid 626.00±26.43ms, without training aid 627.57±22.87ms, P=0.78), canter right rein, with training aid 628.43±24.65 ms, without training aid 626.71±22.76ms, P=0.80).

3.2 Kinetic Data – pressure distribution

In trot, repeatable pressures were recorded beneath the roller in the region of thoracic eleven and twelve. Significantly higher peak pressures (kPa) were found beneath the width of the roller, directly on top of the spinous process in the region of the eleventh and twelve thoracic vertebrae, identified as row C-E cell 9 (Mean ± SD) when using a training aid 38.1 ± 11.1 (figure 1) compared to no training aid 31.3 ± 11.3 (P=0.0007). The peak pressures occurred during both forelimb stance phases. Significantly increased pressures beneath the roller were also seen at cell rows C-E cell 8 when using a training aid 18.9 ± 4.8 compared to no training aid 15.8 ± 6.1 ($P \leq 0.05$) the pressure distribution beneath the roller was more caudal when using the Pessoa training aid. No significant differences (Mean ± SD) in pressures were found either side of the spine identified as row C-E cell 7 when using a training aid 8.4 ± 2.8 compared to no training aid 8.4 ± 2.7 (P=0.92) and rows C-E cell 10 with a training aid 20.8 ± 5.9 and without training aid 19.9 ± 5.9 (P=0.43) (Table 1).

Similar to trot, in canter repeatable pressures were recorded in the region of thoracic eleven and twelve. Significantly higher peak pressures (kPa) were found beneath the width of the roller, directly on top of the spinous process in the region of the eleventh and twelve thoracic vertebrae, identified as row C-E cell 9 (Mean ± SD) when using a training aid 40.4 ± 12.9 compared to no training aid 32.9 ± 12.0 (P=0.01) the pressure distribution was more caudal when using the Pessoa training aid. The peak pressures occurred during the inside forelimb stance phase. No significant differences (Mean ± SD) in pressures were found either side of the spine identified as row C-E cell 8 when using a training aid 21.2 ± 6.3 compared to no training aid 17.7 ± 8.6 (P =0.13), rows C-E cell 7 when using a training aid 15.0 ± 5.1 compared to no training aid 12.6 ± 3.6 (P=0.78) and rows B-D cell 10 with a training aid 31.4 ± 7.9 and with no training aid 27.6 ± 8.4 (P=0.06) (Table 1).

3.3 Kinematics - IMU

No significant difference for any of the IMU derived movement parameters were found for the LTC and RTC, wither or sacrum when using a training aid compared to no training aid in left/ right or trot/canter. All outcome parameters P=>0.1. (Table 2)

4. Discussion

In accordance with our hypothesis, high pressures directly beneath a roller were found in the region of the eleventh and twelve thoracic vertebrae. Although training aids have received some scientific scrutiny (7, 10, 20) to the authors' knowledge there are no published studies looking at the effect that a roller has on pressures applied to the equine back. Similar to treeless saddles, the roller used in the current study did not have a rigid component (23), as such it is likely that when secured, the roller will be pulled down close to the equine back creating the localised pressures to the epaxial musculature in the region of the eleventh and twelve thoracic vertebrae. The horses used in this study were of similar conformation and had well defined back musculature adjacent to the spinous processes, it is likely if using a roller on a horse which has poor back musculature and protruding spinous processes the pressures would increase.

This study found, without a Pessoa training aid, there were consistent high pressures directly beneath the roller on the most dorsal aspect of the spinous process in the region of the eleventh and twelve thoracic vertebrae (figure 1). Peak pressures were similar to those reported in sitting trot and higher than (>35 kPa) those reported for pressures stimulating back discomfort (22) and vascular occlusion (4.7 kPa). The association between reduced pressures and improved gait characteristics has been shown in respect to saddles (15), bridles (14) and girths (13), where improved locomotion was found as a result of reduced pressures (13-15). It is speculated that by exposing the horse to these pressures beneath the roller, directly on the spinous process, it is likely to alter horse locomotion (23) and create localised back pressures. A large number of training aids require the use of a roller to enable them to be attached and, in keeping with our hypothesis, this study found that pressures beneath the roller in the region of the eleventh and twelve thoracic vertebrae increased when using the Pessoa training aid. Without the Pessoa training aid the area of high pressure was directly beneath the width of the roller with each cell being loaded. When using the Pessoa training aid, the high pressures moved caudally beneath the roller compared to the pressure distribution without the Pessoa training aid. The back strap of the Pessoa training attached to a ring which was positioned on the most dorsal aspect of the roller, directly over the spinous process; it is likely that during locomotion this attachment pitched the cranial edge of the roller up thus creating pressures in the caudal region. The timings in which the peak pressures occurred varied between gaits; in trot, two peak pressures occurred during the stance phases of both the left and right forelimb and in canter, a consistent peak pressure occurred during the stance phase of the inside forelimb. Given the direction of pressures beneath a training roller when using a Pessoa training aid were more caudal, it is speculated that other training aids (side reins) may have higher pressures more cranially; this area warrants further research.

In contrast to our hypothesis we found no statistically significant differences in pelvic ROM from the IMU derived parameters when using the Pessoa training aid compared to no training aid. Although not statistically different, differences in movement were found and when looking at the direction of change, for most IMU locations there was a decrease in ROM in a mediolateral and craniocaudal direction and an increase in a vertical direction in both trot and canter when using the Pessoa training aid. These changes warrant further investigation however, based on previous studies where it has been shown improved gait features were associated with less pressure beneath a saddle (15), girth (13) and bridle (14), it seems likely that the pressure beneath the roller was in some way altering locomotion. Further work should look at the direct mechanics behind these changes in relation to pressures created by a training roller.

The region of the eleventh and twelve thoracic vertebrae is an area of considerable muscular attachment aiding the support of the vertebral column. Studies have shown that the *longissimus dorsi*, responsible for trunk stabilization, is most active at thoracic twelve (24) whilst walking and trotting. In the current study, the roller was positioned in this region, it is speculated that the increased peak pressures observed beneath the roller could have an effect on *longissimus dorsi* activation, this is pure speculation however, this warrants further investigation. The Pessoa training aid has been shown to have an effect on whole horse locomotion, where a reduction in speed, stride length, head angle, and lumbosacral angle (at maximal hind limb protraction) was reported (10). Based on the current study it seems likely that there is an association between peak pressures and locomotion similar to other studies. Therefore, users of the Pessoa training aid should ensure that there is clearance of the spinous process in order to optimise the benefits of using a Pessoa training aid which have previously been reported (10). This study used a high wither dressage square and a wool pad beneath the roller, despite this, peak pressures were seen. Studies have shown that pads, when used beneath the saddle, are associated with reducing saddle pressures (12); it is likely that using a pad beneath the roller would act as a dampening effect. Alternatively users could use a correctly fitted saddle and position the roller over the top.

This study did not look at horse locomotion without a roller, to do so would provide evidence on the effect that a roller has on horse locomotion. It only looked at one type of roller and if the study were to be repeated it could be improved by evaluating a leather roller or a modified roller which is designed to provide clearance of the spinous process. Using a treed saddle, providing clearance of the spinous process and roller with a Pessoa training aid would be useful. This study only looked at pelvic ROM, however, using a camera based system would provide detailed analysis of limb loading as well as using IMUs along the spinous process which would provide greater understanding on back kinematics in relation to roller pressures. Although in the current study a wool pad was used beneath the roller it would be interesting to evaluate various pads beneath the roller to determine the dampening effect, if any, which they may have. This study was sufficiently powered (0.94) however, increasing the sample size would be useful especially with the IMU derived parameters. In order to apply these findings in a practical context, future work should look at determining how lunge exercise is performed within the industry.

5. Conclusion

This study found that when using a roller with a high withered dressage square and wool pad, there were localised pressures similar to ridden exercise, located beneath the roller directly on the spinous process. Furthermore, these localised pressures increased and moved caudally beneath the roller when a Pessoa training aid was fitted, likely due to the back strap of the Pessoa training aid attaching to the ring positioned on the back of the roller. Improved manufacturing design is needed to create clearance of the vertebrae, similar to a treed saddle, during lunge exercise. Horse owners, veterinarians, therapists and instructors should be aware of the effect that a training roller can have on back pressures, especially in horses undergoing rehabilitation of back problems. Attempts to alleviate pressures should be made with either a pad creating clearance of the vertebrae or by placing a roller over the top of a correctly fitted saddle.

6. Conflict of Interest Statements

None of the authors of this paper have a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of this paper.

7. Acknowledgements

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Manufacturers' details

[a]Xsens, Enschede, The Netherlands

[b]Novel, Pliance, smaninger Str. 51, 81675 Munich, Germany

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Table 1 – Peak pressures (kPa) found beneath the roller whilst trotting and cantering with and without a Pessoa training aid. Significant (P=≤0.05) peak pressures found beneath the roller at cells C-E 9 in trot P=0.0007 and in canter P=0.01

Cell Location	Gait	Control, Mean Peak Pressure (kPa) Mean ± SD	Training Aid, Mean Peak Pressure (kPa) Mean ± SD	P Value
C-E 7	Trot	8.4 ± 2.7	8.4 ± 2.8	0.92
C-E 8	Trot	15.8 ± 6.1	18.9 ±4.8	0.05
C-E 9	Trot	31.3 ± 11.3	38.1 ± 11.1	0.0007
C-E 10	Trot	19.9 ± 5.9	20.8 ± 5.9	0.43
C-E 7	Canter	12.6 ± 3.6	15.0 ± 5.1	0.78
C-E 8	Canter	17.7 ± 8.6	21.2 ± 6.3	0.13
C-E 9	Canter	32.9 ± 12.0	40.4 ± 12.9	0.01
C-E 10	Canter	31.4 ± 7.92	27.6 ± 8.4	0.06

Table 2

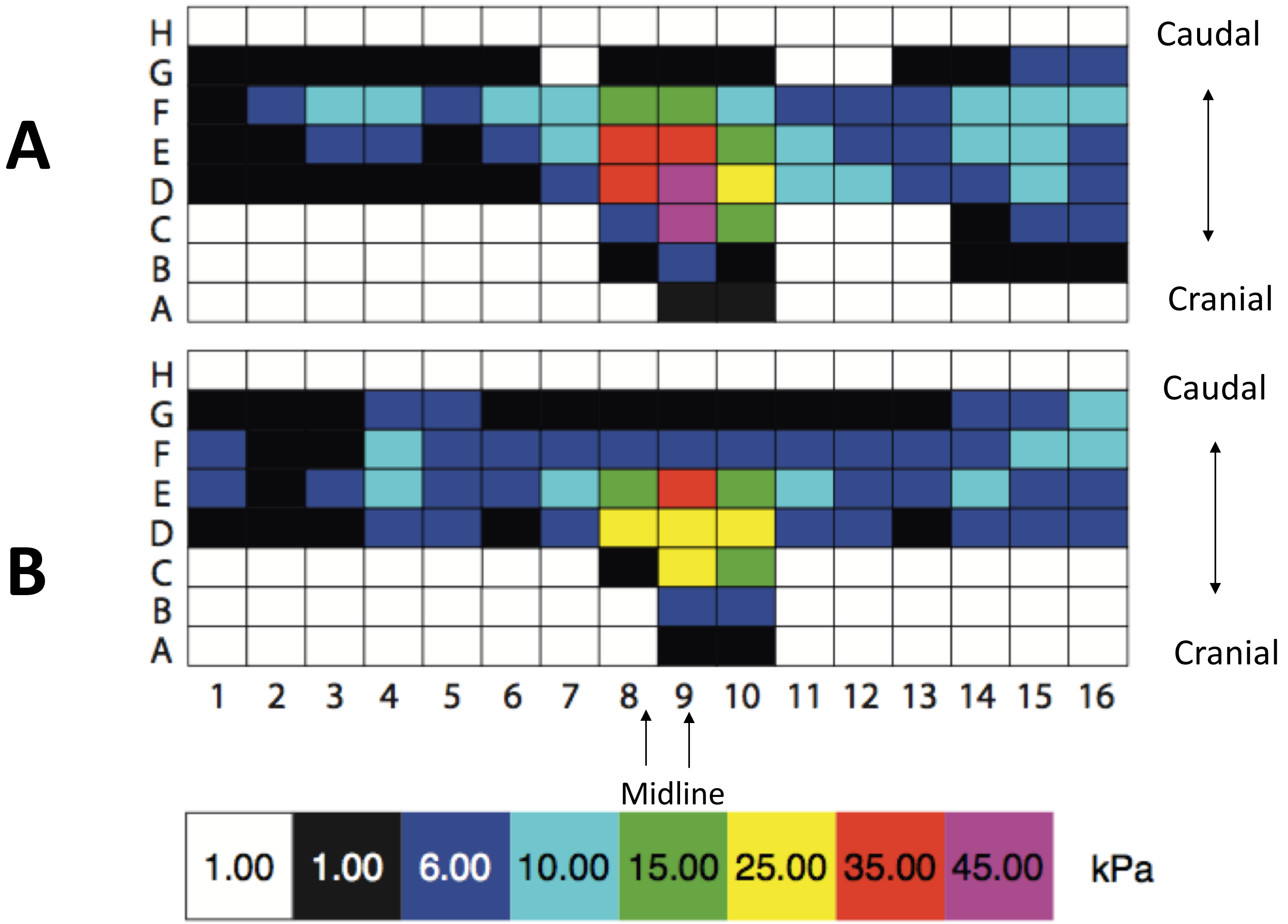
Horse movement data whilst trotting and cantering with the Pessoa training aid and with no training aid. No significant (P=>0.1) differences found between conditions for any inertial measuring unit outcome parameters. (ROMY=range of motion in mediolateral direction, ROMX = range of motion craniocaudal direction, ROMZ = range of motion in a vertical direction).

	Gait	No: of observations	No Training Aid mm (Mean ± SD)	Training Aid mm (Mean ± S)	P Value
LTC ROM Z	Trot	10	97.4 ± 34.00	109.6 ± 15.6	0.30
LTC ROM Y	Trot	10	66.3 ± 41.1	52.7 ± 21.2	0.35
LTC ROM X	Trot	10	36.8 ± 9.1	34.56 ± 11.31	0.76
RTC ROM Z	Trot	10	108. 1 ± 29.60	102.1 ± 32.5	0.18
RTC ROM Y	Trot	10	49 ± 28.6	55.1 ± 40.4	0.22
RTC ROM X	Trot	10	32.2 ± 12.1	34.3 ± 13.4	0.45
Sacrum ROM Z	Trot	10	95.6 ± 10.43	96.3 ±7.6	0.98
Sacrum ROM Y	Trot	10	40 ± 8.6	39.7 ± 10.8	0.91
Sacrum ROM	Trot	10	24.25 ± 4.1	23.6 ± 9.6	0.92

X					
LTC ROM Z	Canter	10	112.3±20.2	115.3±11.8	0.70
LTC ROM Y	Canter	10	48.87±13.7	45.12±7.9	0.27
LTC ROM X	Canter	10	32.5±9.8	27±3.2	0.16
RTC ROM Z	Canter	10	117.8±32.1	125.8±10.7	0.43
RTC ROM Y	Canter	10	39.8±27.7	29.75±5.0	0.34
RTC ROM X	Canter	10	27.2±7.0	26.5±6.67	0.57
Sacrum ROM Z	Canter	10	101.6±13.7	101±12.3	0.83
Sacrum ROM Y	Canter	10	38.8±5.9	36.1±5.6	0.24
Sacrum ROM X	Canter	10	22.8±4.3	21.8±4.7	0.55

Figure 1

Peak pressure (kPa) distribution beneath a training roller when fitted with a Pessoa training aid (A) and when fitted without a Pessoa training aid (B). Peak pressures were found beneath the width of the training roller (B) when fitted without the Pessoa training aid. When fitted with a Pessoa training aid (A) the peak pressures were located more caudally beneath the roller.


A
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11
12
13
14
15
16
Midline
1.00
1.00
6.00
10.00
15.00
25.00
35.00
45.00
kPa

Highlights

1. High pressures found at thoracic eleven-twelve beneath a training roller.
2. High pressures found beneath a training roller when using a training aid.
3. Training rollers should be fitted to ensure clearance of the spinous process.
4. Peak pressures beneath a training roller are associated with gait.