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Alterations in body lean angle in lame horses before and after diagnostic analgesia in straight lines in hand and on the lunge

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ABSTRACT

Altered body lean has been subjectively observed during lungeing in lame horses. The objectives were to quantify the influence of lameness on body lean in trot on the lunge and to investigate the influence of improvement in lameness on the differences in body lean between reins. Thirteen lame horses were trotted in straight lines and lunged on a 10 m-diameter circle on both reins before and after lameness was subjectively substantially improved by diagnostic analgesia. A global position system-aided inertial measurement unit attached to the tubera sacrale quantified body lean. Differences between reins in body lean before and after diagnostic analgesia were calculated and means were determined.

Five and eight horses had unilateral and bilateral hindlimb lameness, respectively. Two of five horses with unilateral and three of eight horses with bilateral lameness leaned more on the rein with the lame or lamer hindlimb on the inside of the circle (difference between reins 5–8°). Two of five horses with unilateral and two of eight horses with bilateral lameness leaned more on the rein with the lame or lamer hindlimb on the outside of the circle (4–10°). Four horses, one with unilateral and three with bilateral lameness, had only 1° difference in body lean angle between left and right reins. When lameness was improved by diagnostic analgesia, the body lean changed significantly towards similar leaning on left and right reins (mean angle changed from 8.8° to 10.0° ($P = 0.03$) on one rein and 13.4° to 10.8° ($P = 0.002$) on the other rein). It was concluded that body lean becomes more symmetrical between reins after improvement in lameness using diagnostic analgesia.

Introduction

Circles are an important part of lameness investigation (Ross, 2011; Greve and Dyson, 2016). During lungeing of horses, differences in body lean angle between turn directions have been observed and it was suggested that this may be due to subclinical lameness or motor lateralities (Brocklehurst et al., 2014). Musculoskeletal pain impairs postural control and stability in man (Hirata et al., 2011). Movement symmetry is altered during circular motion (Starke et al., 2012; Robartes et al., 2013; Pfau et al., 2016; Rhodin et al., 2016). Previous studies in horses have used sensor axial rotation of a sacrum-mounted global position system (GPS)-enhanced inertial measurement unit (IMU) as an indicator of whole body lean angle (Pfau et al., 2012; Brocklehurst et al., 2014). It was demonstrated that when horses move on circles, the tubera sacrale drops to a lower minimum position during the outside hindlimb stance phase compared with the inside hindlimb stance (Pfau et al., 2012; Greve et al., 2017a). This effect is exacerbated with increasing body lean angle (Pfau et al., 2012).

The amount of body lean can be predicted by speed and circle radius. The smaller the radius and the greater the speed, the more the tubera sacrale will drop to a lower minimum position during the outside hindlimb stance phase compared with the inside hindlimb stance (Pfau et al., 2012). It is therefore important to standardise speed and circle radius in order to compare lameness parameters and body lean angles between circle directions (left vs. right reins). A recent study in 13 non-lame dressage horses demonstrated no differences between reins in the difference between measured body lean angle and predicted body lean based on speed and radius of the circle (Greve and Dyson, 2016). Lameness may affect body lean angle, however this remains to be investigated. To date, there have been no studies which quantified the difference between circle directions on the lunge in body lean angle and symmetry measures in horses with lameness before and after reduction in pain by diagnostic analgesia.

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Previous studies have estimated body lean angle from the pelvic roll (i.e., the axial rotation of the pelvis around the craniocaudal axis) averaged over a stride cycle termed 'pelvic roll bias' or 'mean pelvic roll' for an individual horse (Pfau et al., 2012; Brocklehurst et al., 2014). In a group of horses considered sound by their owners the 'pelvic roll bias' of the group of horses as a whole had good correlation to predicted lean angle, based on the speed of the horse and the radius of the circle (Pfau et al., 2012; Brocklehurst et al., 2014). No work has yet been done in lame horses. Horses with hindlimb lameness alter their pelvic and thoracolumbar range of motion and symmetry of motion (Gómez Álvarez et al., 2008; Greve et al., 2017b). The pelvis, lumbar and caudal thoracic region can be described as a rigid body with regard to axial rotation in non-lame horses (Faber et al., 2001). Although it is possible that some horses with lameness in straight lines exhibit a 'pelvic roll bias' that is different from the trunk, it was demonstrated that on average the pelvic asymmetry patterns observed in horses with varying degrees of lameness can be explained by a simple rigid body model, without the need to alter pelvic roll bias (Starke et al., 2015).

The objectives of this study were: (1) to assess the influence of limb pain on equine postural control and stability, measured as mean pelvic roll by a GPS-enhanced IMU, on the lunge comparing left and right reins in trot; and (2) to investigate the influence of alleviation of limb pain on the differences in body lean angle between left and right reins. It was hypothesised that: (1) lame horses lean more on one rein compared with the other; and (2) that alleviation of limb pain reduces the differences in body lean between left and right reins during lungeing.

Materials and methods

A prospective study was performed at the Animal Health Trust (AHT) and Royal Veterinary College (RVC). The study was approved by the Ethical Review Committee of the AHT (Approval number 39 2014; Approval date 12th September 2014) and there was informed owner consent. Six consecutive horses with hindlimb lameness at the RVC and seven at the AHT were included. The same sample of horses had been used to assess thoracolumbosacral movement before and after improvement in lameness by diagnostic analgesia (Greve et al., 2017b). Diagnosis was assigned based on the results of a comprehensive clinical evaluation, diagnostic analgesia and imaging. Age, breed, gender, body mass (determined using a weighbridge), height (copied from the passport) and work discipline were recorded.

Inertial measurement units

Each horse was instrumented with eight MTx (18 g, 1200°/s) miniaturised inertial measurement units (IMUs) (MTi-G, Xsens Technologies). The IMUs were attached to the head (the poll, using a custom-made velcro attachment to the head piece of the bridle) and to the left and right tubera coxae, the withers, the 13th and 18th thoracic vertebrae, and the 3rd lumbar vertebra and one combined IMU/global positioning system (GPS) sensor (MTi-G, Xsens Technologies) at the level of the tubera sacrale (TS) that measured stride-time, speed and radius of the circle during lungeing. For this study, only data from the poll, the tubera sacrale and the left and right tubera coxae were used. The sensors were in custom-made pouches and attached with double-sided tape (F ball Impact Tape, F. Ball). An elasticated surcingle was used to fix the wireless transmitter unit to the horse's body during lungeing. Sensors were attached in two strings (1: head; 2: left and right tubera coxae), tubera sacrale (TS) to the Xbus (Xsens Technologies) transmitting IMU data at a sampling rate of 100 Hz per individual sensor channel.

Dynamic assessment

All the horses were trotted in-hand on a hard surface and then lunged on the left and right reins on a soft surface (waxed-sand with fibre) using a consistent lungeing technique, with a lunge line attached via couplings to the bit rings. The handlers were asked to keep the same lunge line length throughout the entire examination resulting in a circle diameter of approximately 10 m. IMU data were collected for at least 20 s. Notes and video recordings acquired during data collection described deviations from the expected movement condition, e.g., changes in gait, speed or gait quality. If a horse deviated from the required movement condition (e.g., broke into a different gait) data collection was repeated. One trot trial on both left and right reins in trot were recorded for each circumstance. All horses were examined by experienced lameness clinicians (Royal College of Veterinary Surgeons Specialist in Equine Orthopaedics, SD; Diplomate of the European College of Veterinary Surgeons, AFJ, RS). The presence of lameness was graded on a 0–8 scale (Dyson, 2011) under each circumstance before and after diagnostic analgesia. To avoid potential inconsistencies between different grading systems as reported by Hewetson et al. (2006), lameness grading at both centres was performed by one person (LG). All horses were handled by experienced people who were asked to allow the horses to trot at their preferred speeds in hand and on the lunge. The speed was not standardised among horses. The same person handled an individual horse throughout its investigation. All horses were assessed in hand and on the lunge before and after each nerve block. Diagnostic analgesia was performed in all lame limbs and IMU data were collected for at least 20 s under all circumstances after each nerve block.

Data processing

Vertical displacement of the tubera sacrale and the left and right tubera coxae was determined. Processing of IMU data followed published methods (Pfau et al., 2005) with custom-written software in MATLAB (The Mathworks Inc.).

Body lean angle

The mean value of pelvic roll was used as an estimate of body lean angle.

Quantification of kinematic symmetry measures

The following kinematic symmetry measurements were determined: The difference between the two peaks (maxima) (MaxDiff) and two troughs (minima) (MinDiff) of the vertical movement signal for the head and TS were measured and the HipHike Difference (HHD), defined as the difference in upward movement of each tuber coxae during contralateral hindlimb stance (mm). A horse moving perfectly symmetrically would have MinDiff, MaxDiff and HHD values of 0. Detailed description of the calculations can be found elsewhere (Pfau et al., 2012).

Statistical analysis

Sample size calculation

See Appendix: Sample size.

Straight lines

The mean ± standard deviations (SDs) for the directional values of the pelvic roll bias 'body lean angle' before and after improvement in lameness by diagnostic analgesia were determined. Data were assessed for normal distribution using the Shapiro–Wilk test. A paired *t* test was used to determine the difference between the values before and after all diagnostic analgesia.

Lungeing

The differences between left and right reins in body lean angle, speed and stride time were calculated for before and after diagnostic analgesia. Data of body lean angle, speed and normalised stride time on the left and right reins and the differences between reins before and after diagnostic analgesia were assessed for normal distribution using the Shapiro–Wilk test. Mean ± SDs for normally distributed data and median and interquartile range (IQR) for none normally distributed data were determined. Two mixed-effect linear regression models were performed to assess the effect of diagnostic analgesia on the difference in body lean angle between reins with either speed or stride time as covariates. All analyses were adjusted for the clustering effect of the horse by including horse as random effect. Those variables that were statistically significant at $P < 0.20$ were put forward for inclusion in a multivariable, mixed-effects linear model. Final model results were reported as mean and *P*-values. All statistical analyses were performed using SPSS Statistics 20 (IBM) with significance set at $P < 0.05$.

Results

Horse data

See Appendix: Supplementary Table 1.

Subjective grading of lameness

Five and eight horses had unilateral and bilateral hindlimb lameness, respectively. Three and two horses had concurrent sacroiliac joint region pain or forelimb lameness, respectively, and one horse had both. The range of the subjective hindlimb lameness grade before diagnostic analgesia for all the horses was 0–5 both in