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Effect of lungeing on head and pelvic movement asymmetry in horses with induced lameness

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ABSTRACT

Lungeing is an important part of lameness examinations, since the circular path enforced during lungeing is thought to accentuate low grade lameness. However, during lungeing the movement of sound horses becomes naturally asymmetric, which may mimic lameness. Also, compensatory movements in the opposite half of the body may mimic lameness. The aim of this study was to objectively study the presence of circle-dependent and compensatory movement asymmetries in horses with induced lameness. Ten horses were trotted in a straight line and lunged in both directions on a hard surface. Lameness was induced (reversible hoof pressure) in each limb, one at a time, in random order. Vertical head and pelvic movements were measured with body-mounted, uni-axial accelerometers. Differences between maximum and minimum height observed during/after left and right stance phases for the head (HDmax, HDmin) and pelvis (PDmax, PDmin) were measured. Mixed models were constructed to study the effect of lungeing direction and induction, and to quantify secondary compensatory asymmetry mechanisms in the forelimbs and hind limbs. Head and pelvic movement symmetries were affected by lungeing. Minimum pelvic height difference (PDmin) changed markedly, increasing significantly during lungeing, giving the impression of inner hind limb lameness. Primary hind limb lameness induced compensatory head movement, which mimicked an ipsilateral forelimb lameness of almost equal magnitude to the primary hind limb lameness. This could contribute to difficulty in correctly detecting hind limb lameness. Induced forelimb lameness caused both a compensatory contralateral (change in PDmax) and an ipsilateral (change in PDmin) hind limb asymmetry, potentially mimicking hind limb lameness, but of smaller magnitude. Both circle-dependent and compensatory movement mechanisms must be taken into account when evaluating lameness.

Introduction

Accurate detection of the lame limb in horses is a prerequisite for successful diagnosis and therefore important for treatment and recovery. During lungeing, the circular movement is thought to accentuate and, therefore, facilitate visualisation, of low grade lameness. Usually the inside limb is of primary interest, although specific pathological changes may result in more pronounced lameness on the outside limb (Stashak, 2002).

Lungeing has been shown to induce movement asymmetries in sound horses not seen in straight path movement. Differences in the orientation of the torso (Clayton and Sha, 2006), systematically biased symmetry of the head and trunk movement on hard surfaces (Starke et al., 2012), increase in duty factor (i.e. stance/stride time) for the inside forelimb and increased limb and body tilt (Hobbs et al., 2011) have been described. Pfau et al. (2012) found that both speed and circle radius affect movement symmetry. In addition, compensatory movements in the opposite half of the body from the primary lameness have been described (Uhlir et al., 1997; Weishaupt et al., 2004; Kelmer et al., 2005). These compensatory movements may contribute to the variability seen between clinicians when evaluating lameness (Weishaupt et al., 2001; Hewetson et al., 2006; Keegan et al., 2010). Discrimination between lungeing, compensatory movement and pain-related asymmetries are prerequisites for objective, evidence-based lameness assessment.

Despite the common use of lungeing in lameness investigations, it is uncertain how the pronounced circle-dependent asymmetry in movement of the torso affects head and pelvic movement parameters normally associated with lameness. The present study used an objective wireless system based on body-mounted accelerometers and a gyroscope for detection and quantification of lameness (Keegan et al., 2011). The aim of this study was to investigate the

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effect of circle-dependent asymmetries and compensatory movements during lungeing at the trot by evaluating the symmetry of vertical head and pelvic movements in horses with induced forelimb and hind limb lameness.

Materials and methods

Horses

Ten Swedish Warmblood geldings with mean ± standard deviation age of 12 ± 3.4 years, height at the withers of 166 ± 2.5 cm and body mass of 619 ± 45.8 kg were included in the study. Horses were ridden regularly and they were judged as sound by the trainer. The Ethical Committee for Animal Experiments, Uppsala, Sweden, approved the study.

Induction of lameness

Each horse was shod with modified horse shoes with a nut welded to the toe (median plane) on each hoof (Merkens and Schamhardt, 1988). Reversible supporting limb lameness was induced by tightening a bolt which caused pressure on the sole. The amount of tightening needed to induce lameness was determined by an experienced veterinary clinician (LR) subjectively evaluating the motion pattern of the horses trotting in a straight line for 25 m away from and towards the observer.

Instrumentation

Two single-axis accelerometers were taped, one each, to a head bumper attached to the poll and to the midline pelvis between the tuber sacrale, respectively. The accelerometers were oriented with their sensitive axis aligned with gravity (positive upwards). Furthermore, a single-axis gyroscope was strapped to the dorsal surface of the right forelimb pastern to determine timing of right forelimb stance and swing phases of the stride. Sensor data were digitally sampled (8-bit) at 200 Hz in real time. Each sensor had a size of 3.8 cm × 2.5 cm × 1.3 cm and a mass of 30 g. Data acquisition and analysis software were custom-written in Delphi (Borland Software Corp) and Matlab (Mathworks). Detailed descriptions of the equipment can be found in Keegan et al. (2011, 2012).

Data collection

Measurements were collected while horses trotted in a straight line (S) on a level asphalt surface and during lunging to the left (L) and right (R) on a hard gravel-based surface before any lameness was induced. After this, lameness was induced in one limb at a time in random order. The number of straight line measurements was 1–8 (mean 3.6) until, according to the clinician evaluating the horse, a mild lameness (grade 1 on a 0–5 scale) was achieved. Measurements were then collected while the horses were lunged to the right and left.

Data analysis

Vertical head and pelvic accelerations were double integrated and processed using an integration error correction algorithm (Keegan et al., 2001). Vertical position signals of the head and pelvis were decomposed into three sub-components using curve-fitting algorithms: (1) a periodic component at a frequency of 1× stride rate (the first harmonic); (2) a periodic component at 2× stride rate (the second harmonic); and (3) a random, higher-order polynomial component. Harmonics were summated to give composite head and pelvic vertical movement signals without the noise of random motion and average height equal to zero. Relative local maxima and minima were determined from the summated signal (two per stride). Differences in minimum head (HDmin) and pelvis (PDmin) height during right and left stance phases and differences in maximum head (HDmax) and pelvis (PDmax) after right and left stance phases were computed per stride (Fig. 1) (Keegan et al., 2001, 2011, 2012).

Statistical analysis

Mean signed (±) amplitudes, and standard deviations (SDs) of HDmin, HDmax, PDmin and PDmax were calculated for each activity. Normality of the data set was assessed using the Shapiro–Wilks test. Mixed models (SAS Institute) were constructed for outcomes HDmin, HDmax, PDmin and PDmax with horse as random effect. The covariance structure was set to compound symmetry, assuming equal covariance between observations on the same subjects. Direction (S, straight; L, left; R, right), induction (none, forelimb, hind limb) and interactions were included as fixed effects.

Compensatory mechanisms were studied by quantifying the asymmetries in the opposite 'body half', i.e. pelvic excursions (PDmin, PDmax) for induced forelimb lameness, and head excursions (HDmin, HDmax) for induced hind limb lameness. Fixed effects included ± induction, lungeing direction (L/R), a forelimb/hind limb parameter (HDmin, HDmax, PDmin, or PDmax) and all two-way interactions. Each forelimb/hind limb excursion parameter was paired with a corresponding hind limb/forelimb excursion parameter, producing a total of eight 'compensatory' models (HDmin vs. PDmin, HDmin vs. PDmax, HDmax vs. PDmin and HDmax vs. PDmax for forelimb/hind limb and hind limb/forelimb combinations). Independent fore/hind excursion parameters were assessed for linearity against the outcome using four dummy categories ($\leqslant -x$ mm; $> -x$ mm < 0 mm; $\geqslant 0$ mm $< x$ mm; $\geqslant x$ mm); cut-offs for x of 3, 6 and 9 mm were used to achieve reasonably similar numbers in each category.

Full main effect models were reduced, using type III sums of squares, to those containing significant effects, after which two-way interactions were tried. The *P* value limit in all steps was 0.05. Group *P* values and pairwise comparisons were determined and reported.

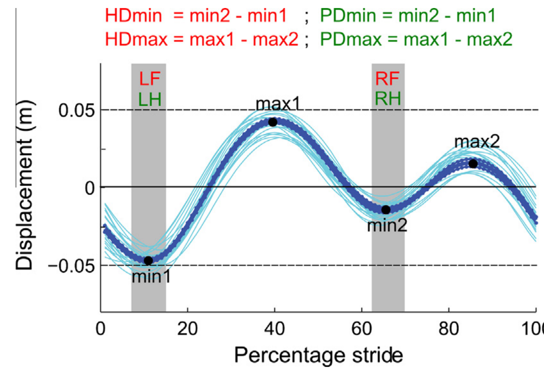

Fig. 1. Vertical head or pelvis movement in a horse with right forelimb or hind limb lameness resulting in positive HDmin and HDmax (for forelimb lameness) and positive PDmin and positive PDmax (for hind limb lameness). Approximate timing of mid-stance is indicated by grey bars. Maximum and minimum heights during/after left and right stance phases for the head (HDmax and HDmin) and pelvis (PDmax and PDmin), respectively.

Results

Descriptive findings

One control (no lameness induction) and four inductions (left front, LF; right front, RF; left hind, LH; right hind, RH), in straight line trot and trotting in the two lungeing directions (L and R) in 10 horses yielded 150 observations with a mean ± SD number of strides of 20 ± 2.8 for S, 28 ± 7.3 for lungeing L and 30 ± 10.8 for lungeing R. Data were normally distributed. The sample was relatively balanced for positive (right) and negative (left) asymmetries before induction of lameness when evaluated in straight line trot. PDmin was least balanced, with two horses having positive and eight having negative values. However mean values were close to zero, indicating almost perfect symmetry (Table 1). After induction of lameness, all horses had forelimb or hind limb lameness parameters of the anticipated, correct sign (negative for left and positive for right limb lameness induction), with absolute values significantly greater than before induction of lameness when evaluated at the straight line trot.

Induction and lungeing direction effects

Hind limb parameters - For PDmin, group value main effects of lameness induction and direction were significant, but the interaction was non-significant (*P* = 0.84). All six pairwise comparisons of direction and induction had *P* values $\leqslant$ 0.001. Magnitude and sign (positive or negative) were balanced for both hind limb lameness induction and direction (Fig. 2). PDmin was significantly more negative after induction of left hind limb lameness and while lungeing to the left, and significantly more positive after right hind limb lameness induction and while lungeing to the right.