The Veterinary Journal 198 (2013) e52–e58

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Head and pelvic movement symmetry in horses during circular motion and in rising trot

Helen Robartes, Harriet Fairhurst, Thilo Pfau *

Department of Clinical Science and Services, Royal Veterinary College, University of London, Hawkshead Lane, North Mymms, Hatfield AL9 7TA, UK

ARTICLE INFO

Keywords:
Equine
Movement symmetry
Rising trot
Circular motion
Inertial sensor

ABSTRACT

Lameness examinations in horses often include lungeing and ridden exercise. To incorporate these exercises into the evidence-based decision making process aided by quantitative sensor based gait analysis, guideline values for movement asymmetry are needed. In this study, movement symmetry (MS) was quantified in horses during unridden and ridden trot on the straight and on the circle. Systematic changes in MS were expected as a result of the 'asymmetrical loading' caused by circular movement, the rising trot and the combination of the two. Out of 23 horses (age 4–20 years, height 13.3–17.2 hands), 13 presented within normal limits for head movement and 22 for pelvic movement. Inertial measurement units assessed MS of vertical head and sacral movement during trot in-hand, on the lunge and in rising trot (straight, left/right circle). Changes in MS between straight line trot and ridden exercise on the circle were more pronounced for the head than for the sacrum. The highest amount of asymmetry was observed during rising trot on the circle (symmetry index of the head: 1.23 for the left rein, 0.83 for the right rein; symmetry index of the sacrum 0.84 for the left rein, 1.15 for the right rein). Change in MS was significant between exercise conditions except for the difference between head displacement maxima. Horses had greatest asymmetry during rising trot on the circle, with MS values of comparable magnitude to mild lameness.

Introduction

Clinical lameness examinations may include assessment of the horse under saddle, particularly when lameness is only very mild in hand, or only detectable or felt when ridden (Ross, 2011). Rider position and symmetry affect horse movement symmetry (MS) and balance, but limited evidence exists that would allow predictions of short or long term effects (Licka et al., 2004; Symes and Ellis, 2009).

Rider presence causes an increase in stance time and maximum fetlock joint extension, particularly in the forelimbs, when trotting (Sloet van Oldruitenborgh-Oosterbaan et al., 1995; Clayton et al., 1999). Rising trot causes uneven loading of the left and right sides, resulting in altered kinematics and loading of the back, pelvis, forelimbs and hind limbs, and a subsequent reduction in MS (Roepstorff et al., 2009). Sitting trot exerts greater stresses on the horse's spine and causes an increase in spinal extension, particularly in the caudal neck region, while rising trot results in greater lateral flexion of the spine (De Cocq et al., 2009). The expertise of riders affects the degree and type (forelimb vs. hind limb) of lameness presentation in a horse (Licka et al., 2004), and a poor rider may even induce a false lameness (Ross, 2011). However, experienced riders may have a stabilising effect on the horse, reducing the variability of kinematic parameters (Peham et al., 2004).

Vertical displacement of the head is commonly used for visual assessment of forelimb lameness and vertical displacement of the pelvis (os sacrum) and tuber coxae for visually assessing hind limb lameness (May and Wyn-Jones, 1987; Buchner et al., 1996). Objectively, a symmetry index (SI), calculating the difference in vertical displacement between left and right steps, or differences in minimum and maximum displacement, and downward and upward displacement, of the head and sacrum may be used to quantify MS (Uhlir et al., 1997; Kramer et al., 2004; Roepstorff et al., 2009; Starke et al., 2012a). Since subjective evaluation of mild lameness shows poor reliability and imperfect agreement (Keegan et al., 2010), objective measures become important for detection of subtle lameness and evidence-based decision making. Inertial measurement units (IMUs) can be used for practical, accurate and precise analysis of horse kinematics (Pfau et al., 2005; Keegan et al., 2010, 2011) and show agreement with subjective lameness scores (Halling Thomsen et al., 2010) and force plate data (Keegan et al., 2012).

During lungeing, horses lean inwards and kinematic alterations of the head and trunk are necessary to balance the horse and produce centripetal force for turning. This causes a physiological

* Corresponding author. Tel.: +44 1707 666327.
E-mail address: tpfau@rvc.ac.uk (T. Pfau).

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http://dx.doi.org/10.1016/j.tvjl.2013.09.033

reduction in MS in sound horses relative to straight line motion (Clayton and Sha, 2006; Starke et al., 2012a). MS further decreases with increasing speed and decreasing radius (Pfau et al., 2012). In practice, lungeing is used to exacerbate mild movement asymmetries that are possibly below the perception threshold during straight line locomotion, or to identify the most affected limb in bilaterally lame horses (Parkes et al., 2009; Ross, 2011). It is unknown how the additional presence of a rider affects horse MS during circular motion.

The aim of this study was to quantify MS in horses during ridden and unridden (rising) trot exercise on the straight and on the circle, exercise conditions that are commonly encountered in a clinical lameness investigation, using horses of variable athletic ability and riders with variable levels of expertise. We hypothesised that systematic changes in MS would be observed between the baseline condition (straight, in-hand) and the remaining exercises as a result of the 'asymmetrical loading' caused by circular movement, rising trot or a combination of both of these movements. In particular, we expected that the most pronounced changes would be observed during rising trot on the circle, when both the rider and centripetal force production impose asymmetrical loading conditions on the horse.

Materials and methods

Participants and procedures

Authorisation was granted by the Ethics and Welfare Committee of the Royal Veterinary College, London (URN approval number 1129). Horse–rider pairs were excluded if horses/riders had suffered injury or lameness within the last 12 months, horses presented with clinical lameness or the horse and/or rider were unable to perform the exercises. Twenty-three horse–rider pairs were recruited for participation (non-elite 'all rounders', without riding specialisation); all horses were considered free from lameness by their owners. Riders wore their usual riding clothes and rode their horses in their usual saddle and bridle. There were nine mares and 14 geldings of different breeds, with age 4–20 years and height 13.3–17.2 hands. Riders ranged in age from 16 to 50 years, in height from 1.50 to 1.80 m and in body mass from 50 to 85 kg.

Multiple six degree of freedom IMUs (MTx, Xsens) and one combined IMU/global positioning system (GPS) sensor (MTi-G, Xsens) were synchronised via a wireless transmitter unit (Xbus, Xsens). Data from each sensor were transmitted at 100 Hz per individual sensor channel to a laptop computer running MT Manager Software (Pfau et al., 2005, 2012; Warner et al., 2010; Starke et al., 2012a).

Sensors were attached to the horse over the poll to the bridle with Velcro and to the withers, the highest point of the pelvis (os sacrum, MTi-G) and both tuber coxae with Animal Polster (Snøgg). Data were analysed from the sensor on the poll ('head nod') and the sensor over the sacrum ('pelvic hike'). The Xbus was fastened to the horse via a surcingle; for the ridden trials, it was positioned in front of the saddle, with the surcingle passing through the girth straps on the saddle pad. Sensor attachment was checked at regular intervals between exercises to make sure that sensors were attached firmly to the required anatomical landmark throughout the whole exercise programme.

Data collection

Unridden - After attachment of the equipment, there was a short 'warming up period', which involved walking/trotting the horses in-hand. Riders led their horses in a straight line in the arena at trot for 2–4 trials of approximately 20 m each. Handlers were instructed to leave the lead rope as long as possible to minimise the influence of the lead rope on natural head movement, whilst still maintaining control. Data were also obtained for trotting on each rein on the lunge in the same arena for at least 2–3 full circles with a diameter of approximately 10–15 m.

Ridden - Riders warmed up their horses according to their normal routines, for no longer than 10 min. Data were collected for rising trot on each rein in straight lines and on a circle of approximately the same diameter as when lungeing. Seven exercise conditions were categorised: (1) uS, 'unridden straight': trot in-hand, on the straight; (2) r_LS, 'ridden left rising trot straight': rising trot on the straight, rising on the left forelimb (LF)/right hind limb (RH) stance diagonal, riding on the long side of the arena; (3) r_RS, 'ridden right rising trot straight': rising trot on the straight, rising on the right forelimb (RF)/left hind limb (LH) stance diagonal, riding on the long side of the arena; (4) uC_L, 'unridden left rein circle': lunged on left rein; (5) uC_R, 'unridden right rein circle': lunged on right rein; (6) r_LC_L, 'ridden left rein circle': rising trot on left rein, rising on the LF/RH stance diagonal; (7) r_RC_R, 'ridden right rein circle': rising trot on right rein, rising on the RF/LH stance diagonal.

Data analysis

Custom scripts written in MATLAB (R2010, MathWorks) were used to process sensor data (Pfau et al., 2005; Starke et al., 2012a). Stride segmentation was achieved using the pelvic (sacral) sensor, based on the maximum downward velocity as an approximation of foot contact of the LH identified by sensor roll (Starke et al., 2012b). Sensor data were rotated into a horse- and gravitation-based, right-handed Cartesian reference frame (*x*-axis: cranio-caudal axis of the horse, forwards positive; *y*-axis: medio-lateral, positive towards left; *z*-axis: vertical, upward positive). Vertical acceleration was double-integrated into velocity and displacement. Vertical displacements of head and sacrum were used to quantify a modified version of the SI, with a value of '1' indicating perfect symmetry and deviations from this to either side indicating left or right sided asymmetry (Uhlir et al., 1997), as well as intra-stride differences in minimum (MinDiff) and maximum (MaxDiff) vertical displacement (Keegan et al., 2004; Kramer et al., 2004), using the following equations:

$$\mathrm{SI} = \frac{\mathrm{Amp}_{\mathrm{up},1} - \mathrm{Amp}_{\mathrm{up},2}}{\max(\mathrm{Amp}_{\mathrm{up},1}, \mathrm{Amp}_{\mathrm{up},2})} + 1$$

$$\mathrm{MinDiff} = \mathrm{Min}_1 - \mathrm{Min}_2$$

$$\mathrm{MaxDiff} = \mathrm{Max}_1 - \mathrm{Max}_2$$

with $\mathrm{Amp}_{\mathrm{up},1}$ referring to the upward movement between LH mid-stance and the maximum height after LH stance, and $\mathrm{Amp}_{\mathrm{up},2}$ referring to the same displacement during and after RH stance. For the head movement, related to the synchronised use of diagonal pairs during trot, $\mathrm{Amp}_{\mathrm{up},1}$ refers to the movement during/after the RF stance and $\mathrm{Amp}_{\mathrm{up},2}$ to the movement during/after the LF stance. In a lame horse, an SI value >1 relates to RH or LF lameness (with decreased upward movement caused by the RH/LF diagonal) and a value <1 refers to LH or RF lameness (with decreased upward movement caused by the LH/RF diagonal). Min_1 represents the minimum observed during LH/RF stance and Min_2 represents the minimum observed during RH/LF stance. Similarly, Max_1 refers to the maximum vertical height reached after LH/RF stance and Max_2 to the maximum vertical height reached after RH/LF stance. In a lame horse, positive MinDiff values relate to LH/RF lameness (with reduced limb compression in the affected LH or RF) and positive MaxDiff to a reduced push-off after the affected RH or LF stance.

Statistical analysis

Statistical analysis was performed using SPSS version 19 (IBM SPSS Statistics) and MATLAB. Median and interquartile ranges (IQR) were calculated across all strides for each exercise condition for each horse. Normal distributions of these median and IQR values across all horses and conditions were confirmed using the one-sample Kolmogorov–Smirnov test (all *P* values >0.134). One-way analysis of variance (ANOVA) was used with a Bonferroni post hoc correction to assess differences between conditions (ΔSI, ΔMinDiff and ΔMaxDiff) at $P < 0.05$, using the following equations:

$$\Delta\mathrm{SI}_{\mathrm{head,pelvis}}(\mathrm{c}) = \mathrm{SI}_{\mathrm{head,pelvis}}(\mathrm{c}) - \mathrm{SI}_{\mathrm{head,pelvis}}(\mathrm{uS})$$

$$\Delta\mathrm{MinDiff}_{\mathrm{head,pelvis}}(\mathrm{c}) = \mathrm{MinDiff}_{\mathrm{head,pelvis}}(\mathrm{c}) - \mathrm{MinDiff}_{\mathrm{head,pelvis}}(\mathrm{uS})$$

$$\Delta\mathrm{MaxDiff}_{\mathrm{head,pelvis}}(\mathrm{c}) = \mathrm{MaxDiff}_{\mathrm{head,pelvis}}(\mathrm{c}) - \mathrm{MaxDiff}_{\mathrm{head,pelvis}}(\mathrm{uS})$$

where the uS category was taken as the baseline condition, to which the remaining exercise conditions (c) were compared by calculating differences between conditions within each horse, in an attempt to account for small differences in 'baseline MS'.

To exclude mildly lame horses from further data analysis, data from 10 horses (10 values for head, 1 for sacrum) with baseline SI values (during in-hand trot on the straight) outside our predefined range of 0.82–1.18 (head), and 0.83–1.17 (sacrum) (Buchner et al., 1996) were excluded from statistical analysis (Table 1). Given that the included 'sound' horses cover a considerable range of baseline MS values to either side of perfect symmetry (value of 1), emphasis was placed on the analysis of the observed changes in MS values between the baseline values and the values obtained for the remaining exercise conditions.

Results

Baseline movement symmetry

MS for the in-hand assessment on the straight was variable between horses (Table 1). Movement was more symmetrical for the sacrum (one horse outside normal range) compared to the head (10 horses outside normal range).