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Comparison of subjective lameness evaluation, force platforms and an inertial-sensor system to identify mild lameness in an equine osteoarthritis model

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ABSTRACT

When mild lameness exists, agreement between clinicians is often controversial due to its subjective nature. The goal of the study was to compare subjective and objective methods to identify the presence of mild lameness using an established model of osteoarthritis (OA) in which OA was induced by creating a unilateral carpal osteochondral fragment (OCF) in the middle carpal joint of 16 horses. Subjective lameness evaluations (blinded and unblinded), force platforms (FP), and an inertial-sensor system (ISS) were used to detect forelimb lameness at four time points. Limbs identified as lame by each method were compared as well as compared with the OCF limb at each time point. Spearman correlations were calculated between all outcome parameters.

Independent of time, blinded subjective evaluation (54%) and the ISS (60%) identified a higher percentage of horses as lame in the OCF limb compared to FP (40%). Blinded subjective evaluation and the ISS agreed which forelimb was lame more often (50%) compared with blinded subjective evaluation and the FP (38%). Induction of mild lameness within the OCF limb was supported by an increase in the frequency of horses considered lame by both subjective evaluations the ISS and a decrease (3.6%) in mean (among all horses) peak vertical force from baseline to post OCF induction. The percentage of horses identified as lame in the OCF limb, independent of time, was highest with the ISS (60%) followed by blinded subjective evaluation (51%) and the FP (42%). It was concluded that the best agreement was between subjective evaluation and the inertial-sensor system.

Introduction

Lameness is the most common reason that horses present to veterinarians (USDA, 2001; Animal Health, 2013). Subjective lameness evaluation is the accepted standard for clinical lameness detection and includes visualization of local, regional and whole-body movements to identify lameness (May and Wyn-Jones, 1987; Buchner et al., 1996a, 1996b; Weishaupt et al., 2004). Unfortunately, agreement in subjective evaluation of mild lameness is only 50–60% (Keegan et al., 1998, 2010) and poor agreement continues to fuel the development of objective methods to detect and quantify lameness both in a clinical and research setting.

Force platform (FP) analysis has been proposed as the gold standard for objective lameness diagnosis and is routinely used in research settings to quantify lameness and the response to various treatments (Weishaupt et al., 2004, 2006; Clayton et al., 2005; Ishihara et al., 2005, 2009; King et al., 2013). Peak vertical force (PFZ) and stance duration (SD) have historically been the most reliable ground reaction force parameters used to characterize lameness (Weishaupt et al., 2004, 2006; Clayton et al., 2005). Limitations to conventional FP evaluation include poor mobility, the fact that only one stride or foot strike per limb can be recorded at a time, and the cost of equipment and facilities that generally limits its use to a research facility (Weishaupt et al., 2004; Keegan, 2007; Keegan et al., 2012).

Inertial-sensor systems (ISS) have been reported to detect lameness reliably and are relatively practical in a clinical setting (Keegan et al., 2002, 2004, 2011a; Keegan, 2007; Starke et al., 2012; Watanabe et al., 2011; Maliye et al., 2013; Moorman et al., 2013a, 2013b). The Equinosis Lameness Locator[1] is a commercially available ISS that has been reported to be used in over 120 equine practices worldwide[2], indicating its clinical acceptance. Current published reports using this system have focused on lameness originating from the foot (Keegan et al., 2012, 2013; McCracken et al., 2012) and have shown it both to be more reliable than subjective lameness evaluation and

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[1] See: http://equinosis.com/ (accessed 3 August 2015).
[2] See List of Lameness Locator users: http://equinosis.com/ (accessed 19 March 2014).

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1090-0233/

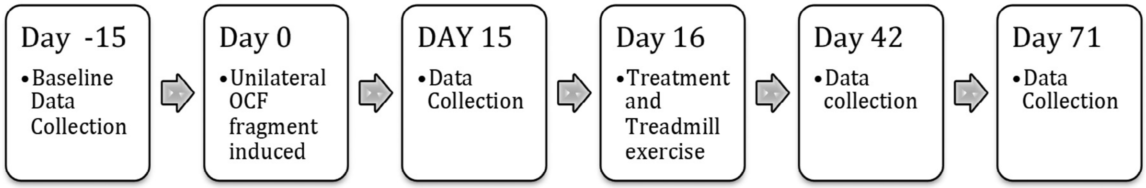

Fig. 1. Schematic illustration of the study timeline.

as reliable as FP in identifying lameness. Two subsequent reports have used the system as the sole method for lameness detection (Schumacher et al., 2013; Toth et al., 2014).

The objective of this study was to determine the percent agreement in identifying the presence of forelimb lameness after creating a carpal osteochondral fragment (OCF) using subjective lameness evaluation, FP, and an ISS. The specific aims were to assess (1) the number of horses identified as having forelimb lameness by each lameness detection method, (2) agreement between methods in identifying the same forelimb as lame, (3) the correlation between the lameness parameters used for each method, and (4) lameness detected within the OCF limb by each lameness detection method.

Material and methods

Study design

Institutional Animal Care and Use Committee approval was obtained for this study (12-3879A, 6 December 2012). The study included 16 healthy horses aged 2–4 years that were shared with another project assessing a novel therapeutic delivery vehicle. Prior to inclusion into the study, all horses underwent physical examination and only horses without abnormal findings were included.

A minimum 14-day acclimatization and training period was provided to introduce new environmental factors and training to an over-ground treadmill and in-hand trotting over dual FP, prior to baseline (Day −10) collection. On Day 0, all horses underwent bilateral carpal arthroscopy. An osteochondral fragment (OCF) was created within the distal aspect of the radiocarpal bone of one randomly assigned forelimb and a sham operation was performed in the contralateral forelimb (Frisbie et al., 2002). On Day 15, the OCF joint was administered a self-complimentary adeno-associated viral vector carrying the equine interleukin (IL)-1 receptor antagonist gene (scAAV-IL-1ra; treated horses, $n = 8$) and the sham operated contralateral joint received a placebo treatment (Gey's balanced salt solution). Untreated horses ($n = 8$) received placebo treatment into both intercarpal joints.

All horses were exercised on an over-ground treadmill starting on Day 16 until the end of the study (Frisbie et al., 2002). Horses underwent subjective lameness examinations and simultaneous collection of ground reaction forces and inertial-sensor data on Days −10 (baseline), 15, 42, and 71 (Fig. 1). Data collection and digital-video recordings were performed on all horses while being trotted in hand by a single experienced handler at a constant velocity along a 25 m runway throughout the study as previously described (King et al., 2013). Videos were randomized by time and horse and four experienced lameness clinicians who were unaware of treatment assignments graded each horse's lameness individually using the AAEP lameness scale[3]. After viewing each video the four clinicians came to a consensus as to which limb was the primary lame limb and the grade of lameness (Table 1). To simulate a true clinical environment, a single experienced equine surgeon performed live subjective lameness examinations, including physical exams and flexion test.

Force platform data collection

Five valid trials of ground reaction forces (GRF) were recorded for each limb by two strain gauge-based FP (Bertec Corporations; 60 cm × 90 cm) mounted in a concrete base in the center of the runway. A valid trial for the FP was determined by confirmation of each limb fully contacting the surface of one force platform at a velocity of 2.7–3.2 m/s and accelerations of ±0.5 m/s^2. Three orthogonal (vertical, horizontal, and craniocaudal) GRFs were analyzed at 3000 Hz; however only vertical and craniocaudal GRFs were analyzed, using Peak Motus software version 9.3 (Vicon) for this study. For comparison purposes between and within subjects, the GRFs were normalized to subject body mass and expressed as N/kg.

Inertial-sensor system data collection

The ISS (Equinosis LLC) consisted of three single-axis sensors (3.8 × 3.8 × 1.3 cm) each labeled to indicate the direction and anatomical location of placement on the horse. Prior to trotting over the dual FP, an accelerometer (Freescale Semiconductor) was secured on the dorsal midline at the poll and tuber sacrale with reclosable fasteners (Dual Lock reclosable fastener, 3M) and tape (Gorilla glue). A gyroscope (Murata Electronics North America) was secured to the dorsal aspect of the right front pastern with an elastic wrap (Taiyo Yuden) and tape (Gorilla glue), used in an attempt to decrease rotation of the elastic wrap keeping the sensor on dorsal midline. A single individual applied the inertial sensors throughout the study. If an FP trial was deemed valid, inertial-sensor data continued to be collected along the same runway until approximately 25 strides had been collected as recommended by the manufacturer. Inertial sensor data were collected, processed and analyzed as described elsewhere, using software (Microchip Technology; Delphi, Borland Software) version 1.10.122.1746 (Keegan et al., 2000, 2001, 2002).

Determination of lameness

Using data obtained from the force plate, lameness was considered present if a significant difference between PFZ and/or SD (average of five trials) was observed at each time point. The limb with the lower mean value of PFZ and/or higher SD was identified as the lame limb (Table 1). Mean values of the ISS data were calculated for length (mm) of the vector sum (VS), angle of the vector sum (AVS) and A1/A2 ratio (AR); thresholds (Table 1) were set according to previously described work (Kelmer et al., 2005; Keegan et al., 2011b). Values for each trial were taken from a data output sheet generated by the ISS (Fig. 2).

Statistical methods

Descriptive statistics were performed on all FP and ISS data. Paired *t* tests were used to determine if there was a significant (P value ≤ 0.05) difference between PFZ or SD of the left-right forelimbs over the five trials for a single horse and time point. Spearman rank correlation coefficients (r) were calculated to identify correlations between outcome parameters for the three different lameness detection methods. Correlations were categorized as strong ($r \geq 0.8$), moderate ($r \geq 0.6$), mild ($r \geq 0.4$) or weak ($r < 0.4$; Pearce and Frisbie, 2010). Statistics were performed using SAS version 9.3.

Table 1
Criteria used for identifying the presence and localization of forelimb lameness by subjective lameness evaluation, force platforms, and an inertial-sensor system.

Method	Does forelimb lameness exist?	Which forelimb is lame?
Unblinded subjective evaluation	• AAEP lameness scale (≥1)	• Forelimb with the highest lameness score
Blinded subjective evaluation	• AAEP lameness scale (≥1)	• Consensus of four clinicians
Force platforms	• Significant left from right forelimb differences in PFZ or SD based on paired t-tests.	• Forelimb with the lower PFZ or longer SD
Inertial-sensor system	• VS ≥ 6 mm • AR ≥ 0.5	• Right forelimb lameness : AVS (0–180°) and right forelimb AR (≥0.5) • Left forelimb lameness: AVS (180–360°) and left forelimb AR (≥0.50)

PFZ, peak vertical force; SD, stance duration; VS, vector sum; AR, A1/A2 ratio; AVS, angle of the vector sum.

[3] See: http://www.aaep.org/info/horse-health?publication=836 (accessed 3 August 2015).