OBJECTIVE MEASURES OF LAMENESS EVALUATION
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Subjective evaluation of the horse in motion is the standard of practice for detection and evaluation of lameness in horses. Techniques for subjective evaluation are first learned in veterinary school and later developed by collegial transfer of knowledge, study of standard veterinary texts, and by experience. Nothing is better than experience at improving this skill. How one looks and what one looks for when detecting and evaluating lameness varies from practitioner to practitioner that is dependent somewhat on the type or breed of horse and activity being evaluated. “Head nodding”, whether it refer to the up or downward movement of the head, limb movement and the shape of the hoof flight arc, how the foot lands, stride length, joint angle changes, “hip hikes” and “hip dips”, gluteal muscle rise and “use”, certain behaviors under certain activities, like not being able to take the right lead at a canter easily; all of these and more have been described in veterinary texts and manuscripts and presentations. Frequently the examiners, through experience, know whether or not the horse is lame and the limb involved, perhaps without being able to describe what is seen exactly. It is definitely one of the “arts” of equine practice.

With such variability in subjective technique it is understandable that, even between experienced practitioners, some disagreement in detecting lameness, grading severity, grading improvement after blocking or treatment, picking the limb with the primary lameness, is expected. Subtle movement signs that happen very quickly, below the temporal sampling ability of the naked human eye, and compensatory movements due to unloading the limb with primary lameness that mimic lameness in another limb, contribute to this disagreement. It has been shown that experienced clinicians are significantly more consistent, i.e. agree with themselves, at detecting mild to moderate lameness (60% above chance) than veterinarians in training (40% above chance), but agreement between experienced clinicians is no better than between younger, less experienced ones (20% above chance). Agreement between experienced clinicians for detecting a change in lameness was only 19% above chance. Detecting hind limb lameness is more difficult than detecting forelimb lameness, especially when the severity of lameness is mild. In one in depth study of over 100 horses simultaneously evaluated by 3 clinicians, detection of forelimb and hind limb lameness when the mean AAEP score was >1.5, was >90% (>40% above chance). However, when the mean AAEP score was <1.5, agreement for forelimb and hind limb lameness was only approximately 60%, or just slightly above chance. Testing after full lameness evaluation, including lunging and flexion tests, compared to testing only by observing the horse trot in a straight line, degraded agreement. It has also been shown that prior assumption of a block being performed during a lameness evaluation can bias clinicians into grading lameness less by up to 1 AAEP grade. The 95% confidence interval for repeatability between clinicians for grading lameness in horses is about 1.5 grades. Results of these studies suggest 2 broad concepts; 1) if you are going to use subjective evaluation of lameness as an assessment tool in clinical studies it is best to use one, and only one, experienced clinician, and 2) finding small, but nevertheless significant, differences between treatment groups for reduction in lameness after treatments in clinical studies will be difficult without large numbers of experimental subjects. Utilizing numerical scales with greater numbers of divisions than the
AAEP lameness scale or an (analog) continuous scale may be a better alternative. Certainly, in clinical trials, the evaluator should also be blinded to treatment status.

An alternative to subjective is objective lameness evaluation. Objective methods of lameness evaluation are resistant to bias and are usually more sensitive than simple subjective observation and grading. They are more sensitive due primarily to the capability of a higher data sampling frequency. The higher data sampling frequency detects and records shorter duration events and smaller movement changes characteristic of mild lameness. Objective methods are also more precise because the lameness scale is continuous (analog) with test-retest repeatability a smaller ratio of full scale range. For example, for the stationary force plate, random change from one trial to the other is less than 10%, with an expected full range change in a horse with grade 4 left forelimb lameness to grade 3 right forelimb lameness of +/- 50%, for instance after a block. Thus the random change to possible change ratio is 10 %/( 2 x 50%), or 10%. By comparison the repeatability of subjective evaluation (1.5 grades) divided by the possible full range using the AAEP scale (+/- 4 grades) is 1.5/ (2 X 4) or 18.75%.

**Kinetic Technique**

Most lameness is painful during weight bearing causing the horse to bear less weight on the affected limb during the stance phase of the stride. The decreased weight bearing can be manifest as a decrease in peak force during limb contact or a decrease in total force per unit time (also called the impulse) of the stance phase of the stride. Measuring ground reaction forces is a direct method of quantifying lameness in horses. The stationary force plate is the most commonly utilized and cited technique.

During an evaluation for lameness with the stationary force plate the horse is moved over the force plate so that at least one, and preferably just one, hoof strikes the force plate completely within the confines of the surface of the force plate. Ground reaction forces can be measured in all 3 directions; vertical, horizontal and transverse. Decreased vertical ground reaction force and to some extent, altered horizontal ground reaction forces, are most often associated with lameness in the horse. Peak forces and impulse (area under the force versus time curve) increase with severity of lameness. Shape of the vertical and horizontal ground reaction force signals may also contain information relevant to determining timing of lameness, differentiating if pain is maximum during limb impact, in the first half of stance or during pushoff, in the last part of stance.

The stationary force plate is a precise and accurate instrument. Variability between trials is low (coefficients of variation below 10%) and sensitivity is high enough to detect subclinical lameness.\(^5\) Acquiring data requires controlled conditions. The hoof must strike completely within a relatively small area, often requiring multiple attempts. Speed of movement is also controlled, both to increase the chance of successful hoof strike and to decrease variability between hoof strikes. The stationary force plate is a gold standard for objective lameness evaluation in horses.

Although it has been shown to vary with breed, the forelimb of sound horses trotting across the force plate at moderate speed will strike the force plate with force approximately equal in magnitude to 100% of its body weight.\(^6\) Horses with AAEP grade 4 lameness will strike the forelimb with a force as low as 50% of its body weight.\(^6\) These estimates are not available for hind limb lameness.

Using the force plate to assess lameness in horses is time consuming. Equipment set up is complex with environmental and space restrictions. Each limb must be sampled and assessed for a complete examination. Simultaneous, stride-by-stride correlation between limbs is not
possible. Other potential kinetic techniques and their advantages and disadvantages compared to the stationary force plate are listed below.

1. Pressure Mats or “in-shoe” systems (http://www.tekscan.com/equine-gait-analysis). Reported to be less repeatable than the stationary force plate for detecting vertical ground reaction forces.7 Stationary and “wireless” systems are available. Measures only vertical ground reaction forces. Not as durable as the stationary force plate.


“Line-of-site” based kinematic techniques

Kinematics is the measurement and study of movement. Limb and torso pain will alter the normal movement of the horse. If pain predominates in one side of the body the normal, symmetric movement between right and left parts of the stride will become asymmetric. Kinematics, like kinetics, can be used to quantify absolute movement measures that may correlate well with lameness, but most applications quantify lameness by measuring the asymmetry of movement between left right sides of the body. Many different motion parameters have been studied and used to detect and evaluate forelimb and hindlimb lameness in horses, including vertical movement of the torso (head bob, pelvic fall and rise), stride and step length and timing, pelvic rotation (hip hike and dip), limb and hoof flight pattern, and joint angle extremes and range of motion. Asymmetric vertical movement of the torso, because it is more directly associated with vertical ground reaction force, is most likely the most sensitive kinematic measure of asymmetry of movement due to lameness.

Body motion changes due to lameness are more variable than changes in ground reaction force. Variability can be decreased by either strictly controlling conditions of evaluation or collecting multiple contiguous strides or both. The most common line-of-site kinematic technique is camera-based. The horse is filmed while moving and body motion is quantified by analyzing trajectories of markers attached to the body of the horse. Camera-based kinematic technique is more sensitive than subjective evaluation for detecting asymmetry of motion because the sampling rate of the camera can exceed the temporal resolution of the unaided human eye. In order to collect multiple contiguous strides and maximum spatial resolution, kinematic evaluation of lameness in horses is usually performed on the equine treadmill. More cursory evaluations to detect less subtle lameness and to assess large changes in lameness severity may be accomplished by collecting fewer, non-contiguous strides with the horse moving in front of the camera multiple times (http://www.youtube.com/watch?v=dvz3ZyUNM0Q). At the present time there are commercially available, two-dimensional systems that are optimized for use in the horse, see http://www.mi-as.com/applications/biological-and-veterinary-sciences/, and http://equanalysis.webs.com/. However, low inter-day repeatability due to variations in placement of markers limits the clinical applicability of these systems.9 Other, more sophisticated (and expensive), multiple-camera, 3-D systems, with automatic calibration and live marker tracking are also commercially available, but these are used only in a few veterinary research centers.
Body-Mounted Inertial Sensor System

Asymmetry of motion can also be measured using inertial sensors attached to the horse's body. Sensor data can then either be stored or wirelessly transmitted to the evaluator. Motion data from multiple contiguous strides in an over ground setting can be collected and evaluated. Wireless transmission of body-mounted inertial sensor data offers a possibility of using kinematics to objectively evaluate lameness in horses in a natural clinical environment. Full systems are commercially-available to equine veterinarians. See www.equusys.com; www.equinosis.com; www.centaure-metrix.com.

Equusys, Inc. of Sudbury, Massachusetts has developed EquuSense Equine to analyze “equine performance” and lameness. Eight to 18 body-mounted inertial sensor nodes sense motion and transmits to a hub on or near the horse and a workstation with software. Body position, velocity, acceleration, orientation and rotation (+/- 2 mm, +/- 2 degrees) is sampled and transmitted in real time. Data is analyzed to give the user objective output and presented to the user as animated flight paths of body parts or as an animated moving ‘stick figure’ horse. Objective detection and evaluation of lameness routines must be developed by the user. The status of Equusys, Inc. at this time is unknown.

Lameness Locator® by Equinosis® was specifically designed as an aid to the practicing equine veterinarian. It consists of 3 inertial sensors attached to the head, right forelimb pastern or hoof wall, and pelvis. Vertical accelerations of the head and pelvis and angular velocity of the right distal forelimb are measured and wirelessly transmitted in real time to a hand-held tablet computer. Fault detection algorithms are used to detect and quantify forelimb and hindlimb lameness when the horse is trotting. These algorithms were developed from previous kinematic research. Best sensor type and locations were first determined by data mining of accumulated motion data from groups of known sound and lame horses. Lameness is detected and quantified by reporting 1) the ratio of vertical movement due to lameness to natural vertical movement, and 2) the means and standard deviations of maximum and minimum height differences of the head (for forelimb lameness evaluation) and pelvis (for hind limb lameness evaluation) position. Location of lameness to limb and timing of peak lameness within the stride phase of a limb are determined by the association of head and pelvic movement to angular velocity of the right forelimb. Compensatory or multiple limb lameness patterns can be determined by studying the distribution of impact and pushoff asymmetry in all 4 limbs. This system has been determined to have high test-retest (intra-day) repeatability, to correlate well (for forelimb lameness evaluation) with results of the stationary force plate, and to be more sensitive that a consensus of 3 evaluators performing full lameness evaluations. Current studies at multiple institutions have centered on using the equipment to objectively quantify flexion test response, effect of blocking on lameness, compensatory lameness patterns, and lunging. Equimetrix®, marketed by Centaure-Metrix™, is a 3-dimensional, accelerometer system attached to girth of an exercising horse. Torso acceleration is collected and logged as the horse is exercising. The data is analyzed to measure stride characteristics such as regularity, frequency, length and propulsion power. Also available is the Pegasus.f4v system (see http://pegasus.uk.com/wordpress/) body mounted gait analysis system. The author is not thoroughly familiar with this system enough to sufficiently comment on its usefulness to detect lameness in horses.
References