

Core Concepts: Using Vertical Motion of the Torso to Measure Lameness in Horses

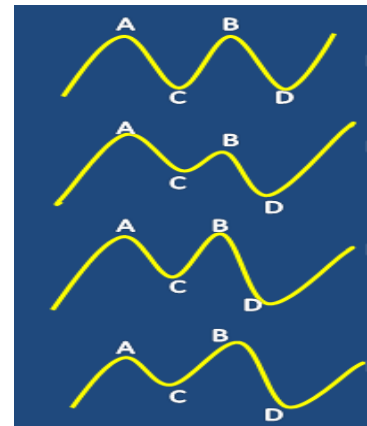
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Lameness in horses is most effectively understood by studying vertical motion of the torso. Vertical motion of the torso follows and therefore mimics the reduced ground reaction forces that occur (and are understood on physical first principles) with lameness.

Forelimb Lameness:

Vertical movement of the head is the most sensitive movement parameter indicative of lameness due to pain in the horse. Vertical head movement is the most efficient method the horse has at its disposal when trotting to decrease force on a forelimb. Vertical head position/trajectory is therefore only dependent upon 1) its natural up and down vertical movement following that of the center of mass of the torso (down during the first half of stance, up during the second half of stance, then repeated on the other limb), and 2) moving upward due to pain. The first component occurs at twice the stride rate, because the head moves down and up twice per stride. The second, if the horse has a unilateral lameness, or if the lameness is consistently greater in one limb compared to the other, occurs once per stride. The gross, or net, vertical head position/trajectory is the simple sum of both components. Timing of the second, or lameness, component relative to the first component determines the shape of the head trajectory.

In horses without lameness, there is no second component at once the stride rate, so the vertical head movement is a simple amplified and delayed version of center of mass movement with height minimums during stance and height maximums between stances. Difference in minimums and maximums in a perfectly symmetric, “robotic” horse will be zero. In reality, no stride is 100% symmetric and there will also be some expected stride to stride variation. With lameness, there will still be the first downward and then upward vertical head movement twice per stride. The overall shape of the trajectory however will be changed. For reference, the beginning of a forelimb stride is when the right forelimb impacts the ground at the beginning of stance. All measurements are relative to the beginning of right forelimb stance. In general, there is depressed downward movement of the head if the pain is in the first half of stance (A to C) and higher upward movement of the head if the pain is in the second half of stance (C to B).



In summary: forelimb force is altered with pain in a forelimb. This is accomplished with a decrease in vertical acceleration, which is measured by the head-mounted vertical accelerometer. Acceleration is converted to vertical position. Vertical head trajectory is processed. Non-periodic vertical movement is extracted. Periodic vertical head movement is summated to produce net vertical head position/trajectory. Differences in minimum and maximum vertical head position are calculated for each stride and measured as a mean over all strides.

Side of lameness is ascertained from the sign of Diff Min Head (positive for right forelimb and negative for left forelimb lameness). Because of the biomechanics of head movement in forelimb lameness, maximum and minimum head heights are related and therefore must be considered together in the determination of both side and timing of forelimb lameness; and to obtain an amplitude of forelimb lameness that takes into account both the upward and downward movement of the head. The composite of these two measures is the vector sum (the square root of the sum of Diff Max Head² and

Diff Min Head² [$c^2 = a^2 + b^2$]), which can be considered the overall amplitude of forelimb lameness. The reference ranges for the lameness measures that serve as an *estimated* level between “lame” and “not lame” were determined experimentally by comparing results from many horses to full subjective lameness evaluation by multiple equine veterinary experts. The 95% confidence intervals of Diff Max Head and Diff Min Head, when the mean AAEP score for the forelimb was zero, was approximately +/- 6 mm.

The approximate threshold for the resultant Vector Sum is 8.5 mm, derived from when Diff Max and Diff Min Head are at their respective thresholds of |6|.

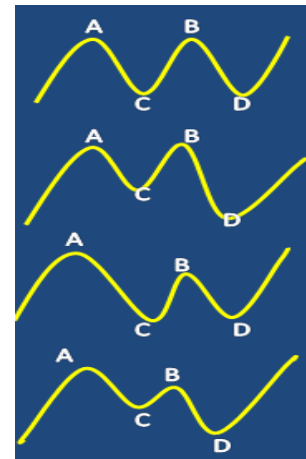
Hind Limb Lameness:

Similar to vertical head movement to indicate forelimb lameness, vertical movement of the entire pelvis (disregarding rotation) is the most sensitive indicator of hind limb lameness. It is better than measures that are not completely dependent upon force in the hind limbs (stride length, pelvic rotation, etc.)

However, because the causes of decreased hind limb loading with pain during impact (extensor muscle activity to reduce pelvic fall, hip hike before impact, shifting weight forward at the beginning of stance) are different than from the causes of decreased hind limb loading during pushoff (extensor muscle inactivity, hip dip from increased limb flexion, shifting weight forward at the end of stance), differences in minimum pelvic height are considered independently from differences in maximum pelvic height. In other words, there is no composite of the two measures, like in forelimb lameness. Diff Max Pelvis measures the pushoff component of hind limb lameness and Diff Min Pelvis measures the impact component of hind limb lameness.

The vertical movement of the pelvis in a horse without hind limb lameness, when the horse is trotting, mimics quite closely the vertical movement of the center of mass of the body, resulting in minimum heights during hind limb stance and maximum heights in between right and left stance. When a horse is painful in a hind limb when it is loading the limb in the first half of stance it will act to reduce the fall (A to C), resulting in differences in minimum height between right and left stance phases. When a horse is painful in a hind limb when it is pushing off in the second half of stance (C to B), it will act to reduce the rise, resulting in differences in maximum height between right and left swing phases.

By convention, positive differences indicate lack of impact or pushoff in the right hind limb and negative differences indicate lack of impact or pushoff in the left hind limb. To keep the general convention of positive for right and negative for left, the beginning of the hind limb stride is at right hind limb foot impact, which is inferred from the timing of right forelimb impact and knowledge that the horse is trotting.



Reference ranges for Diff Min Pelvis and Diff Max Pelvis were determined in the same manner as for forelimb lameness (compared to subjective evaluations of experienced veterinarians, 95% confidence intervals when mean AAEP score was zero). The reference ranges are +/- 3 mm. There is no vector sum for hind limb measures. Diff Max and Diff Min are considered independently of one another.