The Science of Lameness

BY HILARY M. CLAYTON, BVMS, PH.D.
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Lameness is the most common reason that dressage horses miss training days and competitions, and almost every horse owner has to deal with some type of lameness at one time or another. A horse that shows signs of lameness suffers from a functional or structural disorder in his locomotor system. Continuing to work an injured horse usually makes the condition worse. Therefore, riders and trainers need to recognize the signs of lameness so that veterinary advice can be sought early in the disease process—ideally, before irreversible pathological changes develop.

Types of Lameness

Lamenesses have traditionally been classified as *supporting-limb*, *swinging-limb*, or *mixed*. A supporting-limb lameness is one in which signs are visible during the *stance phase* (when the limb is supporting weight). A swinging-limb lameness is one in which signs are visible during the *swing phase* (when the limb is swinging through the air but is not bearing weight). Mixed lamenesses affect both the stance and the swing phases of movement. Gait analysis has shown that almost all lamenesses show changes in the stance phase, and that many also show changes in the swing phase. A pure swinging-limb lameness is seldom seen.

Lameness is manifested as an alteration of a horse's normal gait. Detection and localization of the site of lameness is part of the daily work of an equine veterinarian, who has been trained in the art of visual evaluation of gait and lameness. The practicing veterinarian becomes adept at recognizing not only the overt signs of lameness, but also the more subtle changes that provide clues regarding the cause. In general, it is easy to detect which limb is lame; but only a few types of lameness have a sufficiently characteristic gait pattern that visual evaluation alone is sufficient to pinpoint the precise location within the limb. Examples of lamenesses that have a characteristic gait pattern include sweeney (a shoulder lameness, in which damage to the supraspinous nerve causes paralysis of the shoulder muscles with subluxation of the shoulder joint as the limb bears weight) and fibrotic myopathy (a hind-limb lameness in which scar tissue limits the forward swing of the limb, especially at the walk). The majority of lamenesses, however, do not produce such easily recognized gait abnormalities. In fact, the gait changes tend to be rather generic. Horses use the same methods of reducing the load on a lame limb for many types of lameness that originate at different sites in the limb.

The Mechanics of Lameness

At the Mary Anne McPhail Equine Performance Center at Michigan State University, one of the major goals of our research program is to learn more about the mechanics of lameness. We use high-tech equipment to analyze the movements of lame horses in order to develop a better understanding of the strategies horses use to cope with lameness. One of the most useful tools we have for detecting lameness is the force platform, which is a metallic plate measuring two feet wide by four feet long. It is embedded in the ground, its surface flush with the floor around it. The Brown Force Platform and Runway in the McPhail Center were a gift from Dr. Harold Brown, a veterinarian from Vermont; and his wife, Anne Brown. The force platform and the surrounding runway are covered with poured rubber flooring that provides secure, nonslip footing for the horses as they trot up and down the runway.

The force platform measures the force between a hoof and the ground. When a horse steps on the force platform, his hoof pushes against the ground and the ground pushes back against his hoof with a force called the *ground-reaction force*. The force of the hoof against the ground and the reaction force of the ground against the hoof are equal in magnitude and opposite in direction. The forces can be represented by arrows (or vectors) as shown in Figure 1 below. The length of the arrow is scaled to the magnitude of the force: The longer the arrow, the greater the force. The direction of the arrow indicates the direction of the force. In this diagram, the front-limb force vector is shown at three instants in the stance phase, together with stick figures that represent the orientation of the front-limb segments at the same moments in time.

It is useful and informative to measure the effect of the ground-reaction

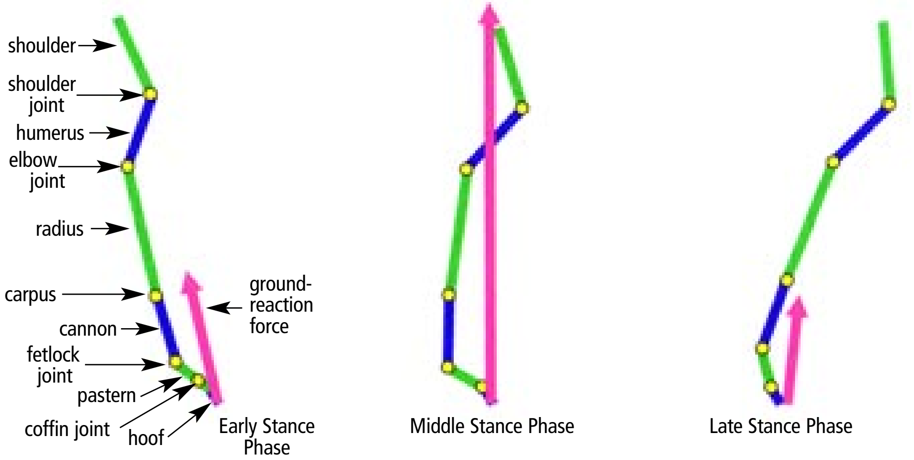

Figure 1. Front-limb stick figure at three stages of stance phase with corresponding ground-reaction force (arrow)

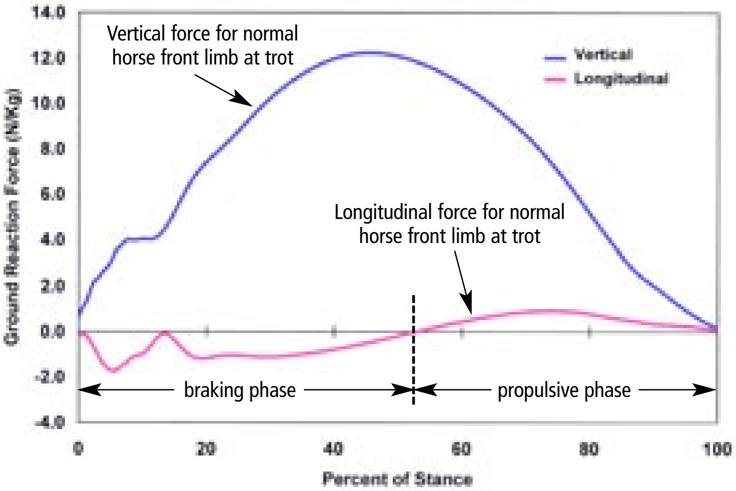

Figure 2. Vertical and longitudinal ground-reaction forces during the stance phase of a front limb at the trot

force in terms of its vertical and longitudinal components. The vertical component of the ground-reaction force supports the horse's weight under the influence of gravity and then creates lift in the stride as he leaps into an airborne phase. The longitudinal component provides braking and propulsion in a forward-backward direction. During the stance phase, each limb initially brakes the forward motion, then provides propulsion.

The vertical and longitudinal components of the ground-reaction force can be shown as graphs. Figure 2 (above) shows typical graphs for a single front-limb stance phase of a trotting horse. The vertical force rises smoothly to a peak around the middle of the stance phase, then decreases. This shows that loading of the limbs is greatest in mid-stance. The longitudinal force has a negative phase (the braking component), followed by a positive phase (the propulsive component). This indicates that the limb tends to slow the forward motion in early stance and to provide forward propulsion in late stance.

Comparing the four limbs' ground-reaction forces gives us information about how each limb contributes to weight bearing and to propulsion. A horse's front limbs normally carry a little more weight than do his hind limbs, as his center of gravity lies closer to his forehand. Consequently, the vertical component of the ground-reaction force is higher in the front limbs than in the hind limbs. The longitudinal component shows braking and then propulsion in all four limbs; but the braking component tends to be larger in the front limbs, whereas the propulsive component tends to be larger in the hind limbs. In the symmetrical gaits (the walk and the trot), the ground-reaction forces are symmetrical in the left and right limbs for both the front- and hind-limb pairs. In the canter, the left and right limbs have different ground-reaction forces due to the different movements and functions of the trailing and leading limbs.

Asymmetry and Lameness

The trot is the gait used most frequently for lameness analysis because it is an inherently symmetrical gait, which makes detection of lameness-induced asymmetries easier to spot. The walk also is a symmetrical gait but generally is less suitable for use in detecting lameness because the slower speed produces lower ground-reaction forces and less-obvious gait changes.

Our research has confirmed that, in sound horses, the force profiles are almost identical in the front-limb and hind-limb pairs. One of the characteristics of lameness is an asymmetry in the ground-reaction force profiles of the left and right limbs. This asymmetry reflects the way that lame horses alter their locomotion patterns to diminish pain. When the lame limb is supporting the body weight, the horse minimizes the pain by decreasing the load on that limb. The decreased weight-bearing on the lame limb shows up as a reduction in the vertical ground-reaction force, often with a compensating increase in the vertical forces in other limbs. At the trot, the front and hind limbs on the opposite side of the body compensate by having higher vertical forces. For example, if lameness causes a reduction in the vertical force in the left front limb, we would expect to see compensatory increases in the vertical forces in the right hind limb (a backward shift) and in the right front limb (a lateral shift).

Ground-Reaction Forces in Lame and Sound Limbs

In a trotting horse, the vertical force varies with his weight and speed. After analyzing many sound horses, we know what the force should be for a horse of a certain size and trotting at a certain speed. Figure 3 (below) compares the vertical forces in the lame and compensating front limbs of a horse with a bowed tendon, as compared to the normal (sound) vertical-force profile in a front limb of a horse of the same size and moving at the same speed. Throughout the stance phase, the vertical force is

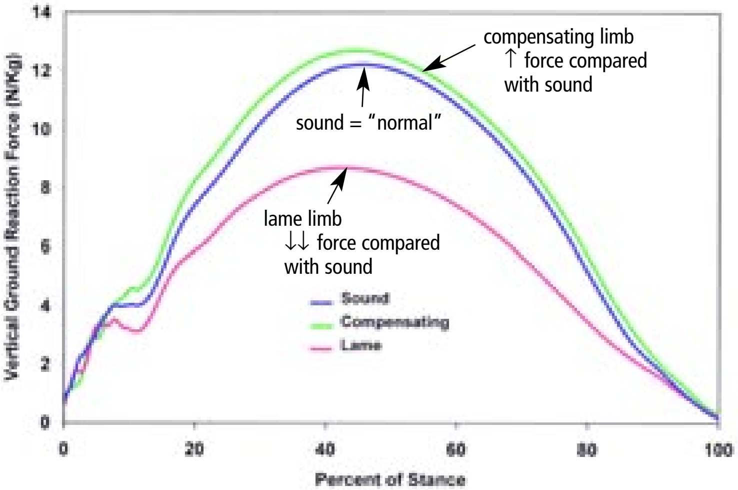

Figure 3. Vertical ground-reaction forces for a sound horse as compared to those for a horse with tendinitis (bowed tendon) in one front limb

considerably lower in the lame front limb than in the compensating (sound) front limb.

As compared to the graph for a sound horse, the decrease in vertical force in the lame front limb is greater than the increase in the compensating front limb. This is because the diagonal hind limb is also playing an active role in the compensation process.

The amount of unloading in the lame limb increases with the degree of lameness, ultimately leading to a horse's bearing no weight (zero vertical ground-reaction force) on the affected limb in a very severe case of lameness. The degree of asymmetry between the lame and compensating limbs increases with the degree of lameness. The amount of asymmetry can be quantified using a symmetry ratio, in which the forces are expressed as a ratio between the lame and compensating limbs. For example, the horse with a bowed tendon shown in Figure 3 had peak vertical forces of 5,200 Newtons (units of force) in the lame front limb and 7,600 Newtons in the compensating front limb. The ratio between the lame and compensating limbs was 0.68, which represents a rather large asymmetry.

In a supporting-limb lameness, the longitudinal braking force usually decreases in the lame limb and is compensated primarily by the opposite limb. In the example of a horse with a bowed tendon, the braking force decreased in the lame front limb and increased in the compensating front limb (Figure 4, below). The longitudinal propulsive force showed less-marked and less-consistent changes.

Compensation Complications

A lame horse attempts to take the weight off a lame limb by redistributing his locomotor forces to his other limbs. The compensating limbs are subjected to abnormally high forces, and these may lead to lameness in the compensating limbs if the problem persists. This point is well illustrated by one of our recent studies of the effects of a bowed tendon (tendinitis of the superficial digital flexor tendon). In that study, the decrease in loading of the lame front limb was compensated by increased loading in the opposite front limb. Computer modeling showed that most of the increased load on the compensating limb was carried by the superficial flexor tendon; normally, the load is more evenly distributed among the superficial and deep flexor tendons and the suspensory ligament. This helps to explain why bowed tendons often occur bilaterally.

Other mechanisms are also at work to ensure a reduced load on the lame limb. One of these involves a change in the timing of the limb movements so that the lame limb spends more time on the ground in the stance phase, thus allowing the vertical force to be spread over a longer period of time and therefore reduced in magnitude. In other words, a lesser force is exerted on the limb over a longer period of time, which allows a more gradual loading and unloading with a smaller peak in the vertical force.

The forces that are measured by the force platform cannot be detected simply by watching a horse move. However, asymmetrical forces are accompanied by asymmetrical patterns of motion. For instance, the angles of the coffin and fetlock joints during the stance phase may differ. A lame horse shows less coffin-joint flexion and less fetlock-joint extension in the lame limb than in the opposite (compensating) limb. The easiest way to see this is to look at the angle of the pastern segment when the limb is loaded during the stance phase. The pastern will be more upright in the lame limb and more sloping in the compensating limb. The angle of the pastern and its effect on the fetlock and coffin joints are consistent and sensitive visual indicators of lameness that, with practice, you can learn to recognize. Interestingly, so-called "supple movers" tend to show more pastern motion and more fetlock-joint extension during the stance phase than do horses that appear to move stiffly.

Lameness and the Dressage Horse

Front-limb lameness. A horse's head and neck normally move up and down in rhythm with the movements of his limbs as he trots. Changes in the head-movement pattern (the characteristic head-nodding associated with lameness) are the best indicators of a forelimb lameness. The head is highest at the start of the lame front limb's stance phase. It has traditionally been assumed that the mechanism of action of the head nod was related to movements of the horse's center of gravity. Experts thought that raising the head shifted the horse's center of gravity backward, resulting in greater loading of the hind limbs and less loading of the front limbs; and that lowering the head shifted the weight toward the front limbs.

Recently, however, researchers have learned that changing the head and neck position produces shifts in the horse's center of gravity that are too small to account for the discrepancy in weight-bearing between lame and compensating limbs. In fact, it has been shown that the head and neck movements are part of a dynamic mechanism that changes the weight distribution between the limbs. To better understand how this mechanism works, try the following experiment.

Stand on your bathroom scale with your arms by your sides. Then quickly raise your arms over your head by swinging them out in an arc in front of your body. Watch the dial on the scale as you do so. As your arms swing up, the

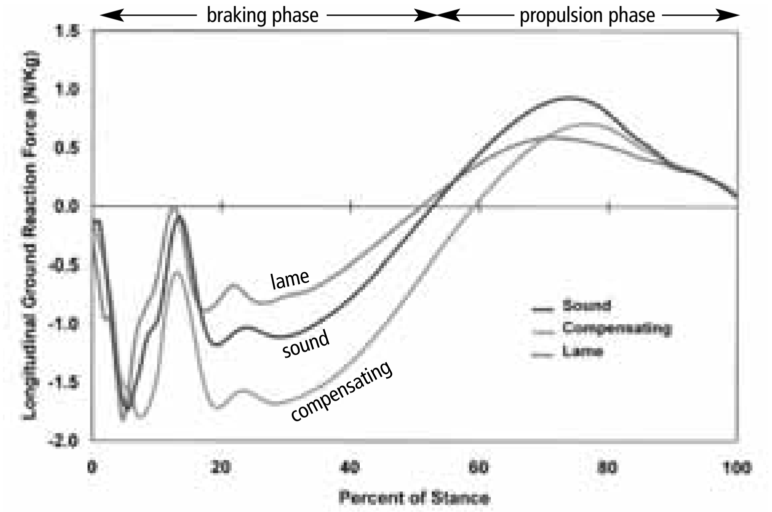

Figure 4. Longitudinal ground reaction forces for a sound horse as compared to those for a horse with tendinitis (bowed tendon) in one front limb

dial indicates that your weight (which represents your ground-reaction force) increases markedly. In the same way, as a lame horse's head and neck swing up, there is an increase in the vertical ground-reaction force on the weight-bearing limb. If we relate the head movements to the stance phases of the limbs, in a front-limb lameness, the head is raised during the latter part of the stance phase of the compensating front limb and is high just before the lame front limb contacts the ground. The head then sinks gradually (if at all) during the stance phase of the lame front limb. The greater the degree of lameness, the less the head is lowered during the stance phase of the lame front limb.

Hind-limb lameness. The movements of a horse's hips and croup are the best indicators of hind-limb lameness. When a sound horse is viewed at the trot from behind, the point of each hip shows a small elevation during stance and a larger elevation during the swing phase of the limb on the same side. In a hind-limb lameness, movement of the point of the hip is increased, and the hip is higher, on the side of the lame limb. You can see the asymmetry most easily just before the lame limb meets the ground, when the point of the hip on that side elevates rapidly. You can also detect these asymmetries by watching the movements of the croup from the side; the croup is highest just before the lame limb makes contact with the ground.

Implications

Gradually, the pieces of the lameness puzzle are falling into place; and we are starting to understand how and why horses adapt their limb and body movements to redistribute the load on lame limbs. Most of the studies to date have looked at front-limb lamenesses. However, hind-limb lameness is common in sport horses. With this in mind, one of our main research initiatives over the next few years will be to focus on hind-limb lameness, especially in the hock joint. Our goals are to study in detail the ways that horses compensate for hock lameness and to evaluate how different types of hock conformation affect the forces on the joint in relation to the development of lameness.

Hilary Clayton, BVMS, Ph.D., is a world-renowned expert on equine biomechanics and conditioning. Since 1997, she has held the Mary Anne McPhail Dressage Chair in Equine Sports Medicine at Michigan State University's College of Veterinary Medicine, East Lansing. The position focuses on dressage- and sport-horse-focused research. Dr. Clayton contributes a quarterly report to USDF Connection *on her team's research efforts and findings, which she hopes will help dressage and sport-horse breeders, owners, riders, trainers, and caretakers to enjoy longer and more productive careers with their animals.*

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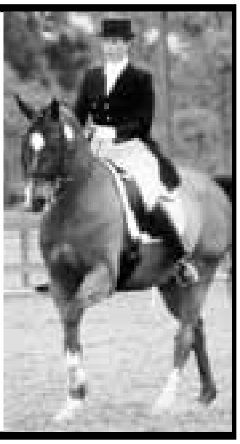

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