Hot to Trot

Second in an exclusive three-part look at the basic gaits

BY HILARY M. CLAYTON, BVMS, PHD, MRCVS

In my last column ("Veterinary Connection," April 2002), I described the mechanics of the walk. This month, I'll explore the trot, with an emphasis on how the gait variables change in the different types of trot.

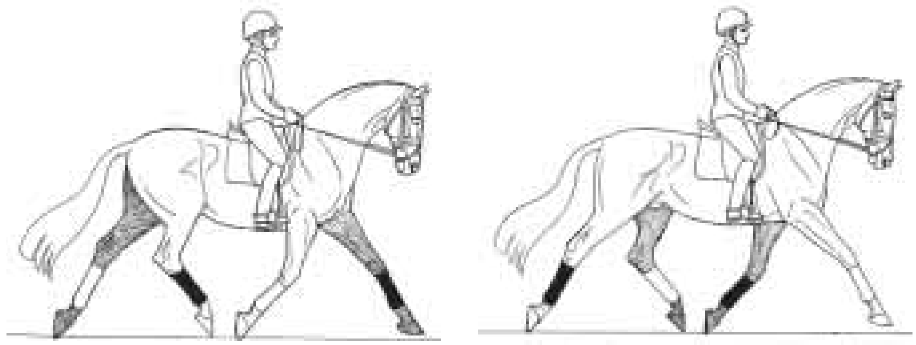
I'd like to begin by reviewing the definition of a stride. A stride is a complete cycle of limb movements. It can begin at any point in the movement cycle, and the starting point does not have any special functional significance. In the trot, the limbs move in diagonal pairs. For the purposes of this article, I've made ground contact of the left hind limb the starting point for the trot stride—but remember, this is an arbitrary choice.

Whatever event marks the start of a stride, the next occurrence of that same event marks the end of that stride.

The Trot Defined

The trot is a "leaping gait," which means that each stride has an *airborne phase* (or suspension). This is in contrast to the stepping gaits, such as the walk, which do not have an airborne phase. In fact, each trot stride has two airborne phases, which separate the diagonal *stance phases* (periods of ground contact).

In the trot, the diagonal pairs of limbs swing back and forth in synchrony in what's called a *diagonal-limb coordination pattern*. The left diagonal comprises the left front and right hind limbs, and the right diagonal comprises the right front and left hind limbs. The time during which a diagonal limb pair is on the ground is called a *diagonal stance phase* (Figure 1). There is a left diagonal stance phase and a right diagonal stance phase in each stride.



ILLUSTRATIONS BY SUSAN HARRIS

Figure 1. The left diagonal stance phase (left) and right diagonal stance phase (right). Left limbs are shaded.

There are several types of trots. As dressage riders, we are familiar with the collected, working, medium, and extended trots. The Standardbred's racing trot is another type of trot, as is the Western-pleasure horse's jog; and these very fast and slow trots have qualities that differentiate them from the dressage horse's trot. I have studied the characteristics of the trot in dressage horses using slow-motion photographic techniques, which measure the gait variables with great accuracy. The findings presented in this article are based on analyses of Grand Prix horses that were competing successfully at the national level.

Trot Speeds

The speed of a gait is calculated as follows:

$$\underset{\text{(meters per minute)}}{\text{Speed}} = \underset{\text{(meters)}}{\text{Stride length}} \times \underset{\text{(strides per minute)}}{\text{Tempo}}$$

Transitions among the various types of trot involve distinct changes in speed: from 192 meters per minute (7 miles per hour) at the collected trot to 217 mpm (7.9 mph) at the working trot, 288 mpm (9.8 mph) in the medium trot, and 296 mpm (10.8 mph) at the extended trot. The most marked change in speed appears to be between the working and medium trots.

The speed of a gait can be changed by adjusting the stride length, the tempo (stride rate), or both. When horses trot on a treadmill at progressively increasing speeds, they adjust both stride length and tempo. Dressage horses are taught to change their speed by adjusting stride length while maintaining an almost constant tempo.

Stride Length

Most of the changes in trotting speed associated with transitions between types of trot are indeed a result of alterations in stride length. In one study of a group of Grand Prix horses, I found that stride length increased from 2.5 meters in the collected trot to 2.7 meters in the working trot, 3.3 meters in the medium trot, and 3.6 meters in the extended trot. The difference between the working and medium trot stride lengths (60 centimeters) was much larger than that between those of the collected and working trot (20 centimeters) or between the medium and extended trot (30 centimeters). Stride length is the distance between successive ground contacts (hoofprints) by the same hoof. In the trot, stride length is the sum of the left and right *diagonal distances* plus the left and right *tracking distances* (Figure 2).

Stride length = Left diagonal length + Left tracking length + Right diagonal length + Right tracking length

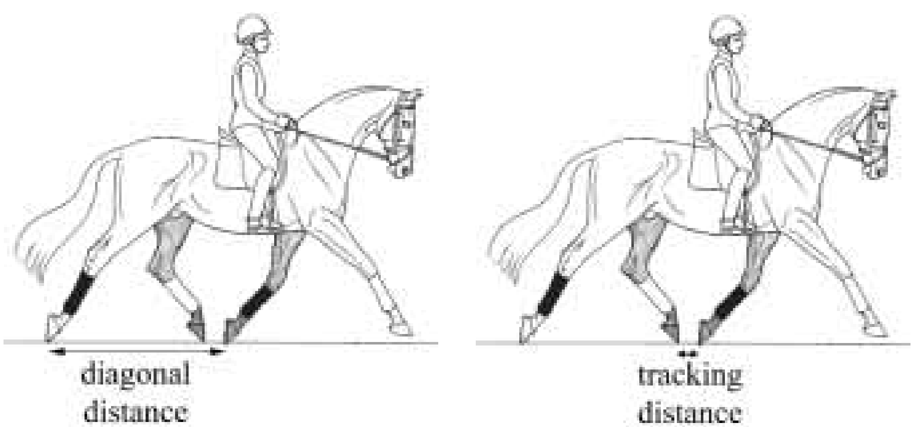


Figure 2. Left diagonal distance and left tracking distance. Left limbs are shaded.

The left-diagonal length is the distance from the right hind hoofprint to the left front hoofprint (that is, the distance between the grounded limbs during the left diagonal stance phase). The right diagonal length is the distance between the left hind hoofprint and the right front hoofprint during the right diagonal stance phase. Usually, the left and right diagonal lengths are equal; but in lame horses or horses that are markedly asymmetrical on the left and right sides, there may be a noticeable difference.

The tracking distance is the distance between the front hoofprint and the subsequent hind hoofprint on the same side. It represents the separation of the left and right diagonals. When the hind hoof steps behind the front hoof, the tracking distance is negative—we say that the horse is "not tracking up" or "undertracking." When the hind hoof steps into the print of the front hoof, the tracking distance is zero and the horse is said to be "tracking up." When the hind hoof steps ahead of the front hoof, the tracking distance is positive and the horse is said to be "overtracking." Tracking up and overtracking are considered desirable because they indicate that the hind limbs are stepping well forward beneath the horse's body.

Comparisons among the different types of trot show that the diagonal distance is about four centimeters longer in the medium and extended trots than in the collected and working trots, reflecting the lengthening of the horse's frame. However, changes in the diagonal distance account for only a small fraction of the change in stride length; most of the adjustment is in the tracking distance. In the collected trot, horses had a negative tracking distance of –7 centimeters, indicating that they were undertracking by about half a hoofprint. Interestingly, the same group of horses showed exactly the same amount of undertracking in the collected walk. In the working trot, they overtracked slightly (4 cm). There was a large increase in tracking distance from working to medium trot (27 cm overtracking), and a further increase of 12 cm from medium to extended trot (39 cm overtracking).

The tracking distances quoted above are averages for a group of warmblood dressage horses. Although all horses' tracking distance increases with trotting speed, conformation, strength, and degree of suppleness affect the degree to which a horse can overtrack. In general, long legs and a short back facilitate overtracking.

The overall increase in stride length from collected to extended trot is almost entirely due to an increase in the tracking distance, which represents the distance covered during the airborne phase of the stride. The longer the horse is airborne, the greater the forward distance he travels during the airborne phase, leading to more overtracking. The best way to prolong the airborne phase is for the horse to project his body higher into the air so that it takes longer for gravity to slow the upward movement and reaccelerate him downward.

Therefore, the secret to achieving a ground-covering extension is that the horse must project his body upward and forward into a lofty airborne phase (Figure 3), which requires considerable muscular effort. Even horses that have not been blessed with a natural extended trot can be strengthened sufficiently to produce a marked increase in stride length.

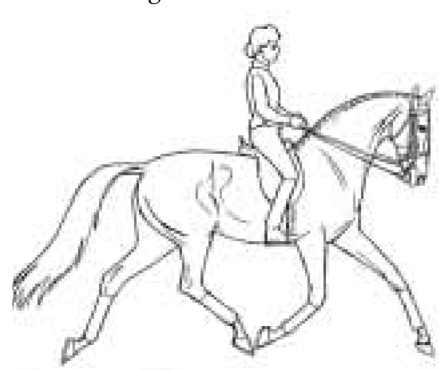


Figure 3. Stride length is increased by projecting the horse high into the airborne phase, allowing the hind limbs to show more overtracking.

A common problem in young horses is that they either forge (clip a front toe with a hind hoof) or travel wide behind (with the hind legs carried further apart than the front legs) when they are first asked to lengthen their trot strides. Both of these faults arise for the same reason: The horse is not yet strong enough or has not learned the technique of projecting his body upward. When he develops more spring and a more defined airborne phase, forging disappears because the front hoof has already left the ground before the hind hoof makes ground contact.

Some horses that tend to forge learn to travel wide behind so that their hind limbs avoid their front hooves. Traveling wide behind is an inefficient method of locomotion and should not be encouraged.

If forging or going wide behind becomes a problem when your horse is learning to lengthen his trot strides, the solution is to do strength-training exercises designed to improve his upward propulsion. Suitable exercises include lengthening and shortening his stride frequently (and within his capability), trotting over raised rails, and trotting up a gradual incline. Exercises that increase the degree of collection (such as shoulder-in), which strengthen the muscles used to elevate the stride, also can be helpful.

Although I have emphasized the importance of the airborne phase in relation to the quality of the trot and the horse's ability to produce a ground-covering extension, the duration of the airborne phase is actually very short: about 40 milliseconds (1/25 second) at the extended trot. The two airborne phases in each stride account for approximately one-tenth of the stride duration.

Tempo

Ideally, a dressage horse should maintain the same tempo in the transitions among the various types of trots. Our group of Grand Prix competitors had, on average, a slightly slower tempo in the collected trot (77 strides per minute) as compared with the extended trot (83 strides per minute). The tempos were measured using sophisticated gait-analysis techniques; the difference is small enough that even an experienced judge would be unlikely to detect it.

Rhythm

The trot should have a regular two-beat rhythm, with the diagonal pairs of limbs contacting the ground synchronously or almost so. The footfalls of the left and right diagonal pairs are separated by equal intervals of time, giving the trot a regular rhythm. Visible irregularities in the trot rhythm are most often associated with an obvious lameness. Slow-motion analysis of the trot stride reveals that the ground contacts and lift-offs of the diagonal-limb pair are often slightly dissociated—not enough to be noticeable to the naked eye, but enough to be visible during slow-motion review. Although the dissociation is small, it yields important information about the quality of the trot. A well-balanced horse that elevates his forehand when he moves usually touches down with his hind limb slightly before the diagonal forelimb (Figure 4). This is called *positive diagonal dissociation* (or positive advanced placement). A few horses make contact synchronously with the diagonal pair, which gives them zero diagonal dissociation, also known as a "square trot." Some horses make contact with the forelimb slightly before the diagonal hind limb (Figure 4), which is called *negative diagonal dissociation* (or negative advanced placement).

Horses with negative diagonal dissociation tend to be more on the forehand than those with positive diagonal advanced placement and therefore can be more difficult to train. However, negative diagonal placement does not prevent a horse from becoming successful in dressage: Our research has shown that about one in five of the horses that qualified for the individual medal competition in the 1992 Barcelona Olympics trotted with negative diagonal dissociation.

Although your eye may not be able to differentiate the ground contacts of the front and hind limbs, you can form a general impression of the contact sequence from the orientation of a horse's body. When the forehand is obviously elevated and he gives the impression of touching down like an airplane landing, he is almost certainly has positive diagonal dissociation. In contrast, the horse that moves on the forehand with his shoulders down probably has negative diagonal dissociation.

Limb Movements

During every stride, each limb has a *stance phase* and a *swing phase*. The stance phase is the period when the limb is in contact with the ground and

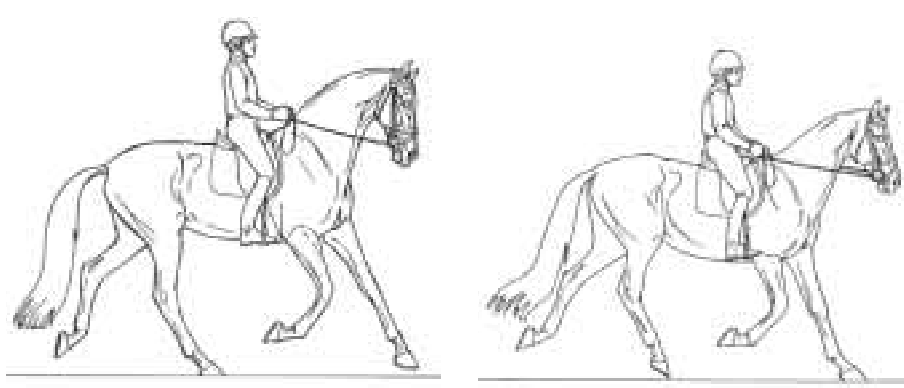


Figure 4. Positive diagonal dissociation (left) and negative diagonal dissociation (right).

is supporting weight; the swing phase is the period when the limb is off the ground and swinging through the air. The swing phase of the limb should not be confused with the airborne phase of the stride. When a horse is airborne, all four limbs are in the swing phase at the same time.

In evaluating the quality of the trot, we tend to focus on the swing phase, as this is the time when the expressiveness of the gait can be appreciated. However, the stance phase has more bearing on propulsion and on the development of injuries, so we should also evaluate the limb movements and alignment of the joints during this phase.

Stance phases of the front and hind limbs are approximately equal in duration. The stance phase is less than 50 percent of the stride duration in gaits with an airborne phase, and stance duration decreases as velocity increases. In the collected and working trots, the stance phase accounts for about 45 percent of the stride duration, while in the medium and extended trots it decreases to about 40 percent of the stride duration.

During the swing phase, the limb swings forward (*protracts*) and is then pulled backward (*retracts*) before the hoof contacts the ground. To produce the longer strides of the medium and extended trots, the limbs must move through a larger range of motion around their pivot points. In the trot, the front limbs pivot around the upper part of the scapula (shoulder blade), and the hind limbs pivot around the hip joint. The range of angular motion (the angle between the limb positions at maximal retraction and maximal protraction) increases by about 7 degrees from collected to extended trot.

The joints of the hind limbs should be well flexed as the limb is protracted. This flexion is most obvious at the hock joint: Look for a small angle on the front of the hock as the hind limb rotates forward underneath the horse's body (Figure 5). This action should not be confused with the type of movement in which the hind limb is snatched off the ground in a stringhalt-like motion but then fails to maintain hock flexion as it swings forward. The front limb should move freely from the scapula, and the elbow joint should be well flexed to raise the knee and the lower part of the limb as it reaches its most forward (protracted) position. The movements should be controlled, keeping the knee and fetlock slightly flexed at maximal protraction. If the movements are not controlled, you may see the horse fling the limb forward and flip up or "flick" his toe. Don't be overly swayed by an expressive front limb; remember the importance of the hind limb in creating impulsion. A powerful motor is ultimately more useful.

Support Sequence

The limb-support sequence describes the number of limbs that support the body sequentially during the stride. In the trot, the support sequences depend on the limb-contact sequence. If the diagonal limbs contact and leave the ground simultaneously, then the horse alternates between diagonal support and airborne phases:

RH-LF : Airborne : LH-RF : Airborne

Horses that show positive diagonal dissociation at contact and lift-off have eight support phases in each stride:

RH : RH-LF : LF : Airborne : LH : LH-RF : RF : Airborne

Horses that show negative diagonal dissociation at contact and lift-off also have eight support phases in each stride: ➤

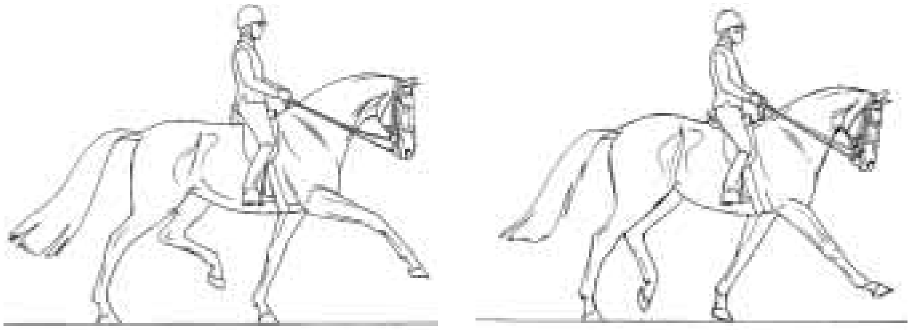


Figure 5. A good mover (left) shows a well-flexed hock and stifle and an elevated front limb at maximal protraction. A poor mover (right) shows much less flexion of the hock and stifle as well as a stiff front limb with a "flicked" toe.

LF : RH-LF : RH : Airborne : RF : LH-RF : LH : Airborne

The periods of support by a single limb are so short, however, that they are apparent only during slow-motion replay.

Ground-Reaction Force

During the stance phase, the hoof exerts a force against the ground and the ground exerts a force against the hoof that is equal in magnitude and opposite in direction. The reaction force of the ground against the hoof is called the *ground-reaction force*, and it causes movements in the horse's body. The ground-reaction force can be resolved into component forces that act vertically, longitudinally (from back to front, along the horse's body), and transversely (from side to side, across the horse's body).

The *vertical force* opposes the effect of gravity. In the trot, the vertical-force curve rises smoothly, peaks in the middle of the stance phase, and then decreases to lift-off (Figure 6). As in the walk, the vertical ground-reaction force determines the amount of sinking of the fetlock joint as the limb bears weight. The forces associated with the trot are considerably higher than those associated with the walk, so the fetlock sinks further in the trot than in the walk. Within the different types of trot, the vertical force increases with velocity, so the fetlock sinks lower in the extended trot than in the collected trot. The ability to develop a large vertical force determines the height and duration of the airborne phase. A large vertical force causes the horse to spring off the ground with a high vertical velocity. This prolongs the airborne time, giving the stride more cadence.

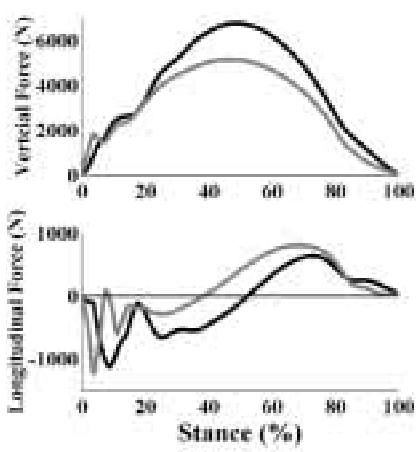


Figure 6. Vertical (above) and longitudinal (below) ground-reaction forces at the trot for the front limb (dark line) and the hind limb (light line).

Early in the stance phase, the *longitudinal ground-reaction force* is negative, indicating that it has a braking effect on the forward motion. Later in the stance phase, the longitudinal force becomes positive, and during this time it acts to propel the horse forward. Increasing the propulsive force or decreasing the braking force increases the speed of the gait. At the trot, the front limbs produce mostly a braking force, which, in combination with the vertical force, elevates the forehand. The hind limbs produce most of the propulsive force that drives the horse forward.

The *transverse* (crosswise) *ground-reaction force* acts toward the midline of the body, and it is small in magnitude when the horse trots straight ahead. Larger transverse forces occur during turns or lateral movements.

Many of the characteristics described in this article are inherent and can be detected by the time a horse is a few months old. However, muscular strength improves with training; and the use of appropriate strength-training exercises will improve gait quality, both in horses that are naturally talented and in those that are less gifted. Muscular strength facilitates elevation of the forehand, with a consequent increase in positive diagonal dissociation. Stronger muscles also increase lift in the airborne phase, which is needed

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Contact: Glenda McElroy, (818) 841-3554, glenda@glenroys.com

September 26–29; Burbank, CA
ABIC/USDF Region 7 Finals, CDS Annual Show & 2002 Southern California Series Finals
Contact: Glenda McElroy, (818) 841-3554, glenda@glenroys.com

SOUTHWEST SERIES

September 28; Scottsdale, AZ
Cool September (Final)
Contact: Jay Chabucos, (480) 513-6377, kabori@aol.com

WEST CENTRAL SERIES

July 31; Huron, SD
Dressage and Sport Horse Breeder's Show
Contact: Sarah Patrick, (605) 875-3592, bterhaar@sullybuttes.net

August 2–4; Mason City, IA
Bara Trac II & USDF Region 4 Adult Championship
Contact: Lloyd Landkamer, (763) 420-2280, llandkamer@aol.com

September 6–8; Mason City, IA
Region 4 ABIC/USDF Regional Finals & Midwest Champ. (Final)
Contact: Lloyd Landkamer, (763) 420-2280, llandkamer@aol.com. ▲

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both to allow the horse to develop more cadence and to maximize his ability to adjust his stride length. The tracking distance remains the most visible indicator of changes in stride length. ▲

Hilary Clayton, BVMS, PhD, MRCVS, 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.*