How to Evaluate Foot Flight and Leg Alignment

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1. Introduction
A disciplined, methodical approach to assessing foot flight and leg alignment can sharpen the eye for details, clearly define each area of concern, and offer a means of classifying specific deformities relative to severity.1,2 This ultimately offers more useful information required for an accurate diagnosis and efficient treatment recommendations. This approach is beneficial for assessing horses of any age, from diagnosing limb deformities in foals to identifying potential high risk factors in pre-purchase exams of adult individuals.

The notion of striving for “textbook conformation” has changed over the years because few if any horses exist that fit this age old model, and many of the cosmetic, unclassified deformities once thought of as flaws are routinely found on superior athletes of most all breeds and disciplines.3,4 Therefore this methodical protocol allows us to better understand variations in distance and structural angles that fall within the range of normal as well alterations that are not compatible with soundness.

2. Materials and Methods
Evaluating conformational correctness as well as undesirable defects and flaws is relative to knowledge of the subject, experience, and level of focus at the time of each exam. Using a systematic methodical approach for every exam offers a useful means of enhancing our ability to record small details that may otherwise be overlooked.

Visualizing planes of reference as imaginary dots, lines, and angles relative to plumb enhances our ability to make comparative, repeatable exams, thereby increasing our powers of observation (Fig. 1). Start by watching the individual walk straight away from you, preferably on a smooth surface. When observing foals, having someone walk the mare along a wall or fence offers a reasonable means of assessing the foal as he travels beside the mare. Focus on foot flight and the landing phase. Watch the hind feet land several times before focusing on the front feet as he travels beside the mare. Focus on foot flight and the landing phase. Watch the hind feet land several times before focusing on the front feet as the individual moves away from you. Foot placement and full load stance appears to occur faster than the eye can detect, but with practice, closely observing the air space under the foot as it lands and loads acts to slow the action and bring out subtle details that might otherwise be overlooked.

Next, observe the foot flight and landing pattern of the front feet as the individual comes back toward you. Watch the lateral wall of each front foot land, then observe the medial wall. Note any differences between the two feet. Turn the individual and watch him walk away from you once again. This time observe the hind limbs, one at a time, from the hip to the ground as the limb flexes and extends to full length. Placing an imaginary dot at each major
joint creates a reliable means of evaluating the angulation relative to plumb as well as the overall sagittal plane of the limb. Once both hind limbs have been observed, focus on the front limbs as the individual continues to walk away, paying particular attention to the carpus and the heel of each front foot. The heeled-out (spiral) deformity and bowed knee (varus carpus) become readily detectable by the trained eye as the individual moves away from you.

As the individual walks back to you, observe only the front limbs, one at a time, from the foot to the shoulder. Once again, place imaginary dots at each joint. Connect the imaginary lines between the dots as the limb flexes and extends and as the foot lands. Foals that are not broken to lead well are more difficult to observe, but with practice the eye can be trained to follow the dot system even at a trot.

Once the individual has been evaluated while moving, observe him standing as squarely as possible and in a relaxed position. Assign imaginary dots in the following 7 places (Fig. 2):

1. Center of toe
2. Center of coronary band
3. Center of fetlock
4. Center of the proximal cannon (note this dot will be superimposed over dot 5 unless axial deformity is present)
5. Center of the most distal aspect of the carpus
6. Center of the distal radius at the level of the physeal plate
7. Most proximal point on the forearm. A small swirl of hair is normally located at the top and center line of the radius.

While observing the dots, visualize an imaginary line between them and note any deviations of the lines. Next, imagine an imaginary laser or arrow centered on each dot, passing through it on the sagittal plane of the limb at that point. Observing these imaginary lines is a reliable, consistent method for identifying planes of deviation that can and often do occur between major joints. Using the dot system and observing the sagittal plane helps train the eye for details that may otherwise be missed, in addition to greatly enhancing communication between those observing the individual.

Limb deformities can be congenital or developmental, with varying degrees of deformity ranging from mild to severe. The majority of deformations will fall into one of five basic categories.

Angular
Angular deformities occur when the distal extremities of the limb deviate from the midline of the limb, normally occurring at the carpus or tarsus. Valgus deformity is a deviation lateral of the mid line.
Varus deformity is a deviation medial of the mid line and normally occurs at the metacarpal/metatarsal phalangeal joint.

Axial
Axial deformities can be described as a medial or lateral shift of the articular surface, for example, off-set knees. The center of the proximal cannon (dot 4) will be located lateral to the center of the distal aspect of the carpus (dot 5). This is not to be confused with the canted knee that is often erroneously referred to as offset. In the case of a canted knee, the two dots are in the same vertical plane.

Rotational (Extorsion)
Rotational deformities are muscular in origin and most commonly occur in front limbs, though they can also occur in hind limbs. The limb from the point of the shoulder to the ground surface rotates outward (extorsion) from the sagittal plane of the horse. Attachment of the limb to the body, chest width, and development characteristics are variables influencing this common deformity. The toed-out stance created by this deformity is often misdiagnosed as a valgus fetlock when viewed from the sagittal plane alignment of the horse.

Spiral (Intorsion)
Spiral deformity occurs within the metacarpus and can occur in the metatarsus. The deformity is an inward spiral or rotation occurring along the long axis of the bone, most frequently in the lower third. This inward twist of the bone is referred to as intorsion, which creates a spiral appearance. An imaginary arrow through the sagittal plane in the proximal metacarpus may be parallel to the sagittal plane of the horse or through the sagittal plane of the carpus when outward rotation is present. However, the sagittal plane through the distal metacarpus will be rotated inward, creating a twisted or spiraled cannon bone. This creates remarkable deviation of the sagittal plane through the face of the knee and face of the fetlock, resulting in a toed-in appearance.

Any given individual may have several types of deformities in any one limb, and the severity of each deformity can be graded on a scale of 1 to 5:

1. Noticeable to the trained eye
2. Noticeable to the experienced horseman
3. Noticeable to the inexperienced horseman
4. Noticeable to anyone
5. Off the scale — catastrophic class deformity

This simple classification scale helps us better commit to the severity of each deformity and how it may relate to treatment goals and prognosis. Developing this assessment system and using it in a disciplined, methodical fashion offers a reliable means of assessing foot flight and leg alignment. Identifying the real problem is a vital step for an efficient treatment protocol.

3. Discussion

Valgus Deformity
Valgus deformities normally involve the distal radial or tibia physis. Most all species of animals that are born with legs longer than the head and neck have a natural valgus carpus that falls within a scale of 2 to 3. Even though this deformity is often considered undesirable in foals, it can be self-correcting from birth up to 18 to 20 months of age.1,2 The exceptionally lengthy closure dates of the distal physis of radius and tibia greatly enhance natural correction that most often occurs during development.

Crushed carpal and tarsal bones can also create valgus angulation between the long bones and may occur in conjunction with physitis. This can be distinguished grossly as well as radiographically (Fig. 3). When assessing angulation between long bones, draw imaginary lines along the sagittal plane and confirm with radiographs when alterations within the carpal/tarsal bones are suspected.

Valgus deformity of the fetlock is frequently misdiagnosed because it is confused with rotation (extorsion) of the entire forelimb. Gross and radiographic examination of exceptionally large numbers of foals indicates valgus fetlocks do not exist unless they are surgically created in an attempt to prevent or correct varus fetlock deformities or occur subsequent to direct injury to the physis. Radiographs of varus fetlocks have a typical sloping articular surface that runs proximal to distal and medial to lateral. A valgus condition would be just the opposite. When overcorrection occurs as the result of surgical intervention, the articular surface slopes inward proximal to distal. Therefore fetlock flexion during the swing phase places the foot in a lateral flight pattern, a very unnatural occurrence.

It is quite natural for all hind limb fetlocks to have some degree of varus alignment. The foot will routinely point toward the tail or midline when this joint is flexed. A perpendicular plane between articulation and digits would allow it to point straight behind the horse; however, this never occurs in nature.

Adverse Sequela
This deformity creates excessive medial heel loading. The further the foot moves away from the sagittal plane of the horse, the more load is placed on the medial heel, resulting in a vertical or rolled under hoof wall, sheared heel (pushed up heel bulb), and weakened medial bar. These early changes can be found in the adult horse long after the majority of the valgus deviation has improved. This predisposes the foot to medial quarter bruising, sepsis, and quarter cracks.
As bone remodels along the lines of stress, the medial wing of the coffin bone undergoes remarkable remodeling that can also be detected radiographically in the adult horse. Venogram studies confirm that vascular alterations and compromised vessels are present in the area of excessive medial quarter loading. This reduced blood flow deprives nutrients to horn growth centers along the medial quarter and sole, resulting in overall diminished growth and permanent medial listing of the palmar surface, a frequently occurring imbalance that is erroneously thought to be farrier induced. Medial quarter bruising and subsequent quarter cracks are major lameness issues with speed horses.

Higher-grade valgus deformities frequently have a varus fetlock, apparently a natural compensating response. Caution is due when attempting to correct a valgus carpus in the first 6 weeks of life, as the mechanical benefits can quickly bring the foot back toward the midline, creating an ideal mechanical stimulus that can perpetuate a varus fetlock. Corrective measures for the fetlock should always take precedence over valgus carpus correction.

A valgus knee on sale weanlings or yearlings greatly diminishes sale value; however, lower-grade valgus knees frequently occur in some of our very best athletes regardless of speed or discipline. Higher-grade 4 to 5 deformities seldom maintain training soundness when subjected to speed and develop a variety of stress-related problems within the carpus, fetlock, and suspensory apparatus.

Varus Deformity

Varus deformity normally involves the fetlock joint, is congenital in nature, and most often becomes more obvious with age and weight gain. An angle forms between the sagittal plane of the metacarpus/metatarsus and distal first phalanx due to diminished medial physeal development of the distal metacarpus (Fig. 4). This is just the opposite of what occurs at the distal physis that creates the valgus limb.

Picking the leg up and holding it with one hand mid-cannon and thumb placed on the center of the tendon, roll the foot into a flexed position using only a forefinger on the pastern (Fig. 5).1 This offers true angle of flexion. Note the angle that forms between thumb, fetlock, and center of heel. Grade 1 classification is very subtle and difficult to detect when viewing the individual standing still but becomes more apparent with the flexion test. This deformity is often confused with spiral deformity but is distinguished from that syndrome because the pure spiral has linear alignment between the center of the tendon, the metacarpal physis joint, and the center of the heel when flexed despite the toe pointing inward.

Unlike the valgus carpus, this deformity does not have a lengthy self-correcting mode due to the short physeal closure dates. Low-grade varus fetlocks are not a serious threat to future soundness; however, a fragile tipping point exists that appears to be balanced by body weight versus growth. Foals that rapidly put on muscle mass in the first few weeks of life often have increasing angulation that can threaten their athletic potential. Therefore, this particular angular deformity requires immediate attention. Good results can be obtained with several methods, provided they are used during the first 6 weeks of life. Because of the very early physeal

Fig. 3. Valgus angle and the angle between the physis and sagittal alignment of the distal metacarpus measures approximately 12 degrees.
Closure dates, varus deformity correction should always be considered prior to valgus carpal corrective measures.

Varus (bowed) knees can be congenital or acquired and are considered a form of varus deformity. They can result from laxity of ligament support structures, rapid weight gain early in life, and/or excessive load caused by contra limb lameness. Early detection and effective lateral support can produce favorable results.

**Ill Effects**

Varus deformity creates excessive lateral heel loading, resulting in a straight or rolled-under lateral quarter, weakened lateral bar, and pushed-up (sheared) medial heel, resembling the sheared heel found with valgus and rotational toed-out deformities. The lateral heel is rarely displaced proximal but can occur in very wide-chested individuals that have a very narrow stance. Sesamoids and associated ligaments and fetlock trauma are common sites for training soreness and structural damage.

**Axial Deformity**

Offset knees is a form of axial deformity. An imaginary dot in the center of the proximal metacarpus and another in the center and distal border of the carpal bones should exist in the same vertical plane.

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**Fig. 4.** A, Foal with grade 2 to 3 varus fetlock left rear and grade 3 to 4 rotational deformity of the entire right rear hind limb. B, Radiograph of a typical right front foot, grade 2 varus fetlock. The articular surface plane slopes distally medial to lateral.

**Fig. 5.** A, Checking for varus deformity. This is a typical grade 4. Note the severe angulation. B, Grade 1 varus fetlock. Note small angulation at the fetlock. Grade 2 spiral deformity is also present. Note alignment from heel to toe relative to sagittal plane of pastern.
However, when the metacarpus has a lateral shift, these dots will not be superimposed or in the same vertical plane.

This deformity is relatively rare compared with other described abnormalities and is often erroneously diagnosed when the entire carpus tips inward but is placed squarely on the proximal cannon, better described as a canted knee (Fig. 6). In this case, the dots are in the same plane but the sagittal plane of the carpus is angled toward the midline relative to the sagittal plane of the metacarpus. Although it may be considered undesirable and is often confused with offset knees, many brilliant athletes have a canted carpus.

Ill Effects
Offset knees are seldom compatible with athletic training prognosis because the asymmetric load distribution puts undue stress on the carpus, splints, ligaments, and tendons.

Spiral Deformity
This deformity is frequently found in light-boned breeds, is congenital in nature, and difficult to detect at an early age. It becomes more obvious as the limb takes on more refinement and distinguishable landmarks. Passing an imaginary arrow through the sagittal plane of the proximal metacarpus and a second through the distal sagittal plane of the meta-

Fig. 6. Note canted carpus right front and spiral cannon (intorsion) with rotated limb (extorsion) left front.

Fig. 7. A, Left front has an inward spiral deformity of the metacarpus and outward rotated upper limb (extorsion). Right front carpus is canted. B, Note the sagittal planes of the proximal and distal articular surface of the right front bone sample. This is a typical spiral metacarpus.
In the carpus, it is evident that an inward spiral has formed between these two planes (intorsion), resulting in a toed-in appearance (Fig. 7). This deformity can occur in conjunction with a varus fetlock or may be found as a predominant defect.

When in its pure form, the flexion test described earlier will confirm that there is no abnormal angulation of the fetlock joint. The deformity occurs within the long axis of the metacarpus. As the individual walks straight away from you, the lateral heel bulb will be quite apparent and the fetlock does not flex out of alignment with the metacarpus despite a toed-in appearance. Therefore, heeled-out is a more accurate description for this deformity. Unlike the varus fetlock, the ground surface of the foot is quite symmetrical and does not allude to the severity of the toed-in appearance. This desirable foot balance is due to a natural load pattern.

The pure spiral deformity can occur in the absence of any degree of varus deformity of the fetlock, although a combination of the two deformities can occur. Because there are stark differences between this toed-in deformity and the varus fetlock, it is better defined as heeled-out. A grade 3 to 4 rotation of the entire limb may have a grade 3 to 4 inward spiral that brings the center of the toe into an acceptable position despite the knee facing outward. This combination appears to be more acceptable as compared with the pure outward-rotated limb and results in a more naturally balanced foot.

**Ill Effects**

This deformity is more of a cosmetic flaw than a structural flaw. Young sale horses with this deformity have greatly reduced sale value because many buyers fail to distinguish this toed-in deformity from the varus fetlock. Many brilliant athletes can be found with various levels of this deformity. There are no known corrective measures.

**Rotational Deformity**

This congenital deformity results in a toed-out posture. It may appear along with valgus, varus, and spiral deformities. In its pure form, limb alignment will be well within acceptable range. To visualize the sagittal plane of each long bone, it is necessary to step to the side of the sagittal plane of the body of the individual and view the limb as a separate component. When the observer steps back to face the individual, the fetlock appears valgus. The imaginary lines through the sagittal planes of each major joint will be aligned in a parallel fashion, confirming acceptable long-bone articular surface orientation. Regarding foot flight and landing patterns, the lateral quarter of the foot invariably lands first and the medial side settles to the ground during peak load. As the entire limb rotates outward from the midline, the lateral heel is physically closer to the ground surface when the limb is extended for the touch-down phase (Fig. 8). Observing the airspace under the foot as it lands helps slow the action, making it more obvious. The higher the grade, the more air space that occurs under the medial quarter as the lateral heel touches the ground.

When this deformity is present, the medial heel is often pushed proximally and toward the apex of the frog, creating a sheared medial heel. This occurs
very early in life as the result of abnormal load distribution to the medial quarter. Contrary to original belief, the lateral quarter that touches down first shows no signs of excessive loading because the weight of the limb has little if any influence on foot shape. The damage occurs to the medial quarter as the body weight is transferred to the foot during peak stance phase. The medial quarter invariably folds inward, preventing end-tubule loading, and the structures within the heel and angle of the foot become compressed due to the ill effects of compartmental syndrome. This creates a very weak, slow-growing heel that can cause soundness and shoeing issues. The effects of excessive medial quarter loading during early development contribute to lack of adequate heel growth, medial listing of the palmar surface, internal bruising, and subsequent quarter cracks, which are common problems that can result from this conformational imbalance early in life.

This deformity is self-correcting in many cases. The Thoroughbred and other breeds with similar body stereotypes often have a very narrow chest cavity that allows the elbow to be tucked in (adducted), resulting in the outward rotation of the entire limb. As the individual matures and the chest develops, the elbows are abducted, rotating the limb inward toward the sagittal plane of the individual. One can demonstrate the real seat of the deformity by sedating a foal or weanling and gently abducting the elbow when the limb is fully loaded, greatly improving the toe-out stance. Colts, as a rule, mature at a much earlier age than most fillies, and many will have a very acceptable stance by the summer or fall of their yearling year, which can significantly improve their sale value. Fillies, on the other hand, require a few more months for full chest maturity.

The Quarter Horse type has a totally different limb/chest arrangement. The pectoral muscles are genetically much more prominent. This heavily developed muscle group typically lies forward of the limb, producing a negative effect as the chest continues to develop. This exceptionally large and conformationally desirable muscle mass creates further adduction of the elbow, forcing a large majority of Quarter Horses to land lateral wall first.

**Ill Effects**

Rotational deformity results in very similar ill effects to what we find in the foot with a valgus knee. Venograms reveal altered circulation of the growth centers, confirming the reason for diminished medial quarter growth rate. Bone remodeling is also present in feet with congenital or developmental imbalance. This deformity, along with the valgus knee, can cause lameness issues in the opposite limb due to interference at high speed and can be a serious concern for farriers as they attempt to direct foot flight.

There are no known means of correcting this deformity using trimming, shoeing, or surgical options. Rotational deformity has caused much confusion concerning the ideal landing pattern and how the foot should be trimmed. The age-old concept that all feet should land flat needs revisiting because this deformity categorically prevents flat landing when the entire limb is rotated lateral to the sagittal plane of the individual. Attempting to make this foot land flat can have serious repercussions because it results in gross distortion of the distal articular surfaces of the fetlock and phalanges and actually increases medial quarter loading.

4. **Conclusions**

We must always be mindful of the natural range of anatomical features that are responsible for overall limb conformation, foot flight, and land/load patterns as well as the limits of the healthy range. Enhancing the eye to visualize an imaginary series of dots and sagittal planes through all major joints during the swing phase and static stance increases our power of observation and offers an efficient means of interpreting the specific planes and how they interact with the limb as well as the horse as a whole.

This methodical approach also offers a means to become more familiar with the range of norm that is influenced by breed, age, use, and environment. Many foals have multifacet deformities, some being compatible with future soundness, others not. Undesirable sale characteristics must be distinguished from potential soundness risk deformities, and, when attempting to correct foals, first and foremost, we must keep in mind what is best for the future of the animal.

**References**