Shoeing in relation to treatment of diseases of the foot has traditionally been taught in a dogmatic and empirical manner, i.e., for disease A, use shoe B. However, our knowledge regarding the physiology of the foot has increased remarkably over the last 25 years and it is a time for a paradigm shift. More specifically, after a diagnosis has been made, it should be possible to determine which structures are associated with the lameness, when these structures are likely to be subject to stress that can be related to the injury, and what biomechanical principles could be used to reduce those stresses. The hoof capsule is subject to compressive and shear stresses, bones and articular surfaces to compressive stresses, while ligaments and tendons are subject to tensile stress. The lamellae are subject to tensile and shear stress. Unfortunately, there are still numerous holes in our knowledge. Therefore, for now, particularly in the absence of controlled clinical studies, we must make the most of what we know, and extrapolate theoretical principles where we can, and combine these with personal experience.

This article looks at some of the biomechanical principles we can attempt to use to change foot function, how the function of a shoe changes with a change in form, and how to combine these two to treat some diseases.

Biomechanical principles for improving foot function

Reducing shock waves/concussion of impact

Impact with the ground at the beginning of the stance phase of the stride, and to a lesser extent the breakover phase, is associated with vibrations within the distal limb. These vibrations are thought to be a factor in the pathogenesis of repetitive stress musculoskeletal injuries. It is known that these vibrations are of greater magnitude and higher frequency in horses shoe with steel shoes compared with the barefoot condition. Certain combinations of pads, plastic and or aluminum shoes have been shown to decrease the magnitude and/or frequency of these impact vibrations. Unfortunately, it is often not possible to determine how effective a combination will be without specifically testing it.

Moving Center of pressure

The center of pressure is the point on the ground surface of the foot through which the ground reaction force works. It is also called the point of zero moment or the point of force. If it is in the center of the foot, then half the weight borne by the limb is distributed on the medial side of the foot and half by the lateral side of the foot. Similarly, half of the weight would be borne by the dorsal half of the foot and half by the palmar half. In a horse standing at rest the center of pressure is in a relatively constant position. In a horse moving the center of pressure varies with the phase of the stride; however, for most of the stance phase of the stride the center of pressure is in a similar position to that of a horse at rest. At this juncture, it is simplest to discuss the center of pressure with reference to a horse at rest yet realizing that it is only part of the equation. If the center of pressure is moved to one side of the foot, it will change the distribution of load causing the wall, bones, joints and lamellae on that side of the foot to be under greater load and on the opposite side of the foot they
will be under reduced load. It may also increase the tension in ligaments on the side of the foot under reduced load.

*Change distribution of force*

The weight of the horse remains constant, but the area of contact between the bottom of the hoof capsule and the ground may vary considerably depending on the nature of the ground. It will also vary depending on whether there is a shoe on the foot and if so what type of shoe is present. Typically, a horse standing on a flat firm surface will have ground contact around the periphery of the foot, whether it is shod or not. In contrast, if a barefooted horse stands on sand the contact is spread broadly across the ground surface of the foot. Therefore, in the former case in which the area of contact is considerably smaller, the parts of the foot in contact with the ground will subject to higher pressure than the foot standing on sand.

If the force is spread out over a larger area in an even manner, then the center of pressure will stay the same. However, if the contact area of one side of the foot is increased relative to another on a soft ground surface, this will change the position of the foot on the ground, which would be expected to change the center of pressure as well.

The ground surface of the sole, frog, and bars are often brought into contact with the ground using various shoeing techniques to decrease weight bearing by part or all of the wall. However, until more is known about how weight is transmitted from the sole to the distal phalanx, and how this varies with differing foot conformations and sole depths, it is difficult to make reliable recommendations regarding this maneuver.

*Torque about the distal interphalangeal joint*

Torque is the tendency to cause a body to rotate about an axis. At rest or during the midstance of the stride the foot is flat on the ground and there is no net movement of the foot in relation to the ground because the extensor moment about the distal interphalangeal joint equals the flexor moment. A moment is the product of the force and the length of the moment arm (that is perpendicular to the force). In the case of the foot on the ground the extensor force is the ground reaction force and the moment arm is the horizontal distance between the center of pressure and the center of rotation about the distal interphalangeal joint. The flexor force is the tension in the deep digital flexor tendon and the moment arm is the distance from the center of rotation of the distal interphalangeal joint to the point on the palmar surface of the navicular bone such that the moment arm is perpendicular to the flexor tendon. Within limits, the magnitude of the ground reaction force is fixed (if in motion, for that phase of the stride) and the length of the flexor moment arm is fixed. Therefore, if length of the extensor moment arm decreases, the tension in the deep digital flexor tendon must decrease if the foot is to stay in the same position. When the flexor moment exceeds the extensor moment the heels lift off of the ground.

When a horse is at rest or at mid stance of the stride the torque about the distal interphalangeal joint can therefore potentially be manipulated by moving the center of pressure to change the length of the extensor moment arm or by changing the tension in the deep digital flexor tendon. The latter is not readily achievable except by performing a deep digital flexor tendon accessory ligament desmotomy or a deep digital flexor tenotomy. The latter is reserved for the treatment of laminitis or severe
flexural deformities. However, the length of the moment arm can be changed by moving the center of pressure towards the center of rotation by elevating the heels in relation to the toe and vice versa.

Changing the most dorsal point of contact with the ground changes the length of the moment arm at which breakover occurs. This may make breakover occur slightly earlier, but does not make the duration of breakover shorter.

### Traction

Traction is a function of the opposing surfaces. Manipulating traction is frequently done to enhance performance, but is seldom performed as a therapeutic measure except to prevent interference, primarily in Standardbreds. There is very little information available on the effectiveness of different techniques to enhance or reduce traction.

### Flight of the distal limb

The flight of the limb during the stride is integrally related to the stance phase of the stride in that how an animal breaks over determines timing and direction of the beginning of flight and the end of the flight phase determines how the foot lands. However, except to encourage the foot to breakover in the most natural position when there is reason to suspect it isn’t or again to limit interference, attempting to modify the flight of the foot is seldom attempted in therapeutic shoeing.

### Structure and function of the horse shoes

#### Material composition and dimensions of the shoe

If a standard shoe is thought of as bar of steel, rectangular in profile, that has been bent to conform to the shape of the foot, then the weight of the shoe is related to the thickness and width of the web, the length, heel to heel, and the density of the material. The weight of the shoe influence the animation of the gait, more weight more animation. However, excessive weight predisposes to injury related to fatigue. The more stiff the material is the more likely it is to transmit impact vibrations compared to a less stiff material. While steel is stiffer than aluminum, a direct comparison of comparable steel and aluminum shoes has not been made to the author’s knowledge. Plastic shoes may be significantly less stiff and some provide protection from impact vibrations. Additionally, any rigid appliance attached to the ground surface of the foot will greatly reduce the ability of one part of the ground surface of the wall to move in relation to another.

#### Cross sectional profile of shoe

The cross sectional profile can be changed in many ways that either effect the whole/most of the shoe or just a part of the shoe. The most common modifications include the addition of creases, changing the width of the web, and changing the profile of the edges of the shoe to create rims. The effects of creases are used to improve traction, and may change the way the foot leave the ground as a result. Increasing the width of the web of the shoe changes the distribution of force; as such it is less likely to descend into a soft substrate, and decreases traction.
Local modifications to the contour of the shoe are primarily utilized at the toe in the form of rolling, rocking or squaring. All of these move the breakover point in a palmar direction and therefore reduce the length of the lever arm at breakover. Rolling the lateral or medial branches of the shoe may also decrease the moment arm in the frontal plane that places compressive stress on the wall and osseous structures on the side that the horse is turning towards and tensile stresses in the ligaments on the contralateral side.

**Bars**

A bar is an addition to a shoe that spans from one branch of the shoe to the other, almost invariably from one heel of the shoe to the other, though other configurations are occasionally used. Bars at the heels increase the surface area of ground contact, limit or apply pressure to part of the foot, and may stabilize the branches of the shoe. As a bar between the heels increases the ground surface contact in the palmar half of the foot, on soft ground it is likely to cause the center of pressure to move towards the center of rotation of the distal interphalangeal joint. The magnitude of the effect will depend on the size of the increase in area and where it is in relation to the center of pressure. For example, a heart bar shoe has a greater increase in surface area than a straight bar shoe and an egg bar shoe extends further from the center of pressure than a straight bar shoe, thus acting as an extension.

**Extensions**

An extension is any part of the shoe that projects beyond the normal perimeter of the foot. Any extension has the potential to act as a lever when the foot is on the ground. When they act as a lever, they cause the center of pressure to move towards the side of the limb with the extension. They are commonly used to force the heels to the ground for foals with flexural deformities of the distal interphalangeal joint and to limit dorsiflexion (hyperextension) of the distal interphalangeal joint with deep digital flexor tendon injury. Lateral or medial extensions are used in foals to treat angular limb deformities.

**Pads**

Pads are available in many variations. In brief, they are generally used to dampen concussion, elevate the foot from the ground, extend the length of the foot or change the balance of the foot. Pads that change the length of the foot or change the angle of the foot in relation to the pastern change the balance of the distal limb. In doing so they may change the distribution of force and shift the center of pressure.

**Attachment of shoe**

Most research has been conducted on steel shoes attached to the foot with nails, so the effects of nailing the shoe on have not been separated from the nature of the shoe. However, a finite element analysis study has demonstrated that stress in the wall is likely to be increased at the heel nail. Another study that examined the effect of gluing on shoes with equilox to the ground surface of the foot determined that the procedure reduced expansion of the foot.
Applying principles and techniques to specific diseases

Laminitis

In laminitis the lamellae at any point around the hoof may become damaged and give rise to distal displacement in various patterns, most commonly rotation (dorsal rotation), distal displacement (sinking), and asymmetrical (medial or lateral) distal displacement. The objective in each case is to remove the stress from the affected lamellae. As they are under greatest stress under tension when bearing load the stress is theoretically reduced by moving the center of pressure away from the affected area. In the case of rotation, the center of pressure can be moved towards the center of rotation, hence decreasing the tension in the deep digital flexor tendon, and thereby theoretically decreasing the tension in the dorsal lamellae. The maneuver does provide clinical improvement in some horses, but it is not without some controversy because a finite element analysis model suggests that it may increase the shear stress in the dorsal lamellae; this apparent dichotomy needs to be resolved. In addition to moving the center of pressure with heel elevation, recruiting ground surface of the frog, bars, and angles of the sole to bear weight to reduced weight bearing by the walls also acts as a mild wedge on a soft ground surface. Lastly, shortening the moment arm at breakover by moving the point of breakover in a palmar direction may decrease the stress in the lamellae at that point in the stride.

Treatment of horses with medial or lateral distal displacement by moving the center of pressure away from the affected side can be achieved by any of the methods outlined above, but the author’s current preference is to use a modest extension on the opposite side of the foot. The procedure is not universally accepted and needs corroboration. As with dorsal rotation, it is usually done in conjunction with modifying breakover and attempting to reduce weight bearing by the wall.

The treatment of distal displacement does not theoretically or in the author’s experience benefit from moving the center of pressure. Recruiting the sole to bear weight with shoeing techniques is also potentially hazardous depending on the functional quality of the sole; however, these horses may benefit substantially by bedding on sand, a maneuver that distributes weight across the center of the ground surface of the foot. When shod, enhancing breakover is as much a logical step as it is with rotation.

Hoof wall defects

Hoof wall defects reduce the ability of the wall to transfer force to the distal phalanx from the ground is impaired, but the lamellae are undamaged. Small defects in the wall only impair this ability to transfer force to a minor degree. However, larger defects can cause the loss of support to the adjacent distal phalanx such that is displaces distally; this may occur dorsally or on either side of the foot. As a consequence of the displacement, the distally displaced distal phalanx compresses the underlying solar dermis in conjunction with prolapse of the underlying hoof capsule that results in bruising and pain. Additionally, if the distal displacement is medial or lateral, it will cause compression of the contralateral distal interphalangeal joint space and tension in the ipsilateral collateral ligament. The defect that permitted the distal phalanx to displace has caused the center of pressure to move away from the area of the defect. Reconstructing the hoof wall defect will restore the center of pressure and symmetry of the distal interphalangeal joint. The treatment of hoof wall defects is in contrast to that of laminitis. In laminitis, moving the center of pressure to the side in which the distal phalanx has moved distally would place the lamellae under greater stress which
should be avoided. Patching hoof wall defects due to white line disease is not usually done because covering the defect may permit the disease process to progress deep to the patch.

**Collateral ligament strain**

The collateral ligament is injured when under excessive tensile stress. To reduce the tensile stress in the ligament during weight bearing, the center of pressure should be moved towards the affected side. This may be achieved by increasing the area of ground contact on the affected side, typically by increasing the width of the branch of the shoe, or by an abaxial extension on the affected side, but the latter maneuver is unlikely to be used on the medial side of the foot because of the risk of interference with the contralateral foot. During breakover the stress in the ligament will be reduced by the moment arm between the opposite to and quarter. This is readily accomplished by rolling the outer rim of the shoe on the opposite branch of the shoe.

**Navicular syndrome**

In navicular syndrome, the navicular disease is under compressive strain from the deep digital flexor tendon and the supporting ligaments are under greatest strain during the second half of the support phase of the stride and breakover. To reduce the tension in the deep digital flexor tendon during the stance phase of the stride the tension in the deep digital flexor tendon can be reduced by moving the center of pressure in a palmar direction towards the center of rotation of the distal interphalangeal joint; this is most readily accomplished by a heel wedge, but any relative increase in the palmar ground contact or extension will act similarly on a soft ground surface. During breakover the tension in the deep digital flexor tendon may be decreased by shortening the extensor moment arm; this is usually done by rolling, squaring, rockering, or setting back the toe of the shoe.