CPD article

Therapeutic farriery of the hind feet for horses with hindlimb orthopaedic injuries

Low heels and negative plantar angles in the hind feet are the most common hind foot conformational abnormality. A causal relationship has been demonstrated between these conditions and hindlimb lameness. It is important these abnormalities are recognised during thorough orthopaedic examinations, so they can be quantified with radiography and appropriately treated with therapeutic farriery to restore optimal hoof conformation, balance and function. This is an essential part of a holistic approach to treating horses with hindlimb lameness. Farriery intervention for these abnormalities involves returning the plantar half of the foot to a load-sharing plane between the frog and heels, restoring phalangeal alignment and providing increased ground surface plantar to the centre of rotation of the distal interphalangeal joint.

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The role of hoof mechanics in delivering maximal performance in horses has been studied in detail and its importance in the front feet has been defined (Davies, 2002). To maximise mechanical efficiency, the hoof should be balanced in both the dorsopalmar/plantar (DP) and mediolateral (ML) planes (Davies, 2002). The definition of the ideal hoof balance is still debated among veterinarians and farriers, but it is accepted that the conformation and balance of both the hoof and distal limb, and their interaction with movement and ground surfaces, are key factors in equine hoof and distal limb health and performance (Johnston and Back, 2006). It has been shown that forces at the toe, and the medial and lateral heels together, are optimally distributed when the hoof and pastern angles are aligned (Balch et al, 1997; Davies, 2002), such as with a straight hoof-pastern axis. Under these circumstances, the angle between the solar surface of the pedal bone and the ground contact surface should be approximately 5° (Back and Pille, 2013). For optimal foot conformation, it is generally acknowledged that this angle should be 2–10° (Parks, 2003). When this angle is negative, it is widely known as a negative palmar/plantar angle (Redden, 2003). Floyd (2010) used a I–IV grading system for treatment and prognosis in horses with negative palmar angles. A grade I is mild, meaning there is sufficient depth under the dorsal margin of the pedal bone and trimming alone will restore a positive pedal bone angle and straight hoof-pastern axis (*Table 1*).

Hoof abnormalities are commonly encountered in clinical practice. Low heels with a broken-back hoof-pastern axis (BB-HPA) are the most common hoof abnormality presented in both the forelimb (Moyer and Schumacher, 1996; Turner, 2010) and the hindlimb (Colles and Ware, 2010).

Table 1: The four-tier grading system of negative plantar angles

Grade	Severity	Definition
I	Mild	There is sufficient sole depth under the tip of the pedal bone, so trimming alone can restore a normal hoof-pastern axis
II	Moderate	Sole depth at the toe is limited, so the best that can be achieved with trimming alone is a zero pedal bone angle. Further improvement to hoof-pastern axis requires shoeing.
III	Severe	Heels, bars, digital cushion and bulbar cushion all compromised. Absence of complete heel mass under wings of the pedal bone. Digital alignment impossible without a special trim and rocker shoe.
IV	Contracted	Severe heel collapse, with additional flexor contracture giving them a post-legged appearance. Vertical orientation of the proximal and middle phalanx and severe hyperextension of the distal interphalangeal joint

Adapted from Floyd (2010)

The repeated application of forces that have a high magnitude and/or an abnormal direction of action, overload the limb and may lead to the development of pathological processes (Johnston and Back, 2006). A negative correlation between forelimb pedal bone angle and the forces applied to the foot, specifically the navicular bone, has been shown (Eliashar et al, 2004). Consequently, a long-toe low-heel conformation in the front feet has been associated with navicular injuries in horses (Wright, 1993).

A long-toe low-heel hind foot conformation has been reported to affect the kinematic variables of the stride, particularly by prolonging hindlimb breakover time (Clayton, 1990). The significance of negative plantar angles in the hind feet has been acknowledged in recent literature, with several studies showing a causal relationship between low heels in the hind feet and concomitant hindlimb lameness. An association between negative plantar angles, the tarsal and proximal metatarsal regions (Pezzanite et al, 2019) and stifle lameness (Clements et al, 2020) has been shown. There can also be an association with gluteal pain (Mannsman et al, 2010) and subchondral bone injury in the plantar aspect of the third metatarsal condyle (Walmsley et al, 2019). Therefore, it is important that hind foot conformational abnormalities are recognised and addressed, as part of a holistic approach to managing horses with hindlimb orthopaedic problems.

Clinical examination

Low-heel hind foot conformation has become prevalent and can be recognised in several ways. When viewed from the side, with the third metatarsal vertically orientated, the digit will have a BB-HPA (*Figure 1*). The hoof capsule may assume a bull-nosed appearance of the dorsal hoof wall, caused by the dorsal edge of the distal phalanx migrating toward the dorsal hoof wall. The growth rings below the coronet are disproportionate, being wider at the toe than the heels. The angle of the coronary band will be acute (40–45°) and a line drawn through the angle of the coronet will form a trajectory towards the elbow, whereas in a horse with good hind foot conformation the trajectory will go to just above the carpus (*Figure 2*) (Schumacher et al, 2012). The horse may also exhibit postural changes, whereby the affected limb is placed further forward than the normal vertical axis and the centre of muscle mass of the hindlimb (Mannsman et al, 2010), which will further increase the load on the heels (*Figure 3*). With this postural adaptation, the broken-back hoof-pastern axis is also often disguised (Hunt, 2005).

The heel bulbs will be prolapsed plantar to the heels of the hoof capsule and may be lying against the shoe. The frog may be located distal to the ground surface of the hoof capsule and be large and bulging, because of constant stimulation by the ground. The heels will be thin and the bars may be absent. If this hoof abnormality is not addressed, the heels in the hind feet will suffer the same structural consequences and hoof capsule distortion as in the fore feet (O'Grady and Merriam, 2007). The horn tubules will deform and bend forward, along with a forward shift of the foot, in conjunction with a reduction of mass in both the heel bulbs and the frog.

Radiographs

It has been reported that horses with hindlimb lameness have been treated with heel elevation (Peham et al, 2006), without

Figure 1: Conformation can be assessed by viewing the horse from the side with the metatarsus perpendicular to the ground. This horse has long toe, low-heel conformation with a broken-back hoof-pastern axis (red line).

Figure 2: Coronet trajectory in a horse with low-heel long-toe conformation and a camped under stance (red line), versus the more ideal hindlimb posture and coronet trajectory (green line).

Figure 3: A horse with postural changes where the right hindlimb is placed further forward than the normal vertical axis and centre of muscle mass of the hindlimb.

necessarily quantifying hind foot balance. It is recommended to obtain lateromedial hind foot radiographs of any horse being investigated for hindlimb lameness or poor performance. Collapsed or underrun heels may cause subtle bilateral hindlimb lameness. As part of a thorough lameness investigation, attempts should be made to ascertain the exact location of pain. Most practitioners will start with a low 4-point nerve block and, if this is positive, subsequent attempts should be made to further localise lameness to the foot, pastern, or fetlock region. There may be safety concerns when performing diagnostic anaesthesia in the hindlimb. In at risk horses, it may be deemed an unnecessary risk to confirm the foot as a source of pain, if foot imbalance can be identified with radiography and be addressed as part of the initial treatment regardless.

Lateromedial radiographs are quick, easy and can be safely obtained in a well-sedated horse, with the third metatarsal orientated vertical. The radiographs should be centred on the distal interphalangeal joint (DIPJ) and collimated to include the distal aspect of the third metatarsus, so the hoof-pastern axis can be fully evaluated. Radiographs give an abundance of information to assist veterinarians and farriers with therapeutic intervention. This includes the length of the toe, plantar pedal bone angle, solar depth at toe and heel and the COR of the DIPJ, relative to the widest part of the foot (*Figure 4*). To evaluate the centre of rotation of the DIPJ, a plumb line is dropped from the centre of the second phalanx condyle, this should then land in the middle of the weight-bearing surface. With low-heel conformation the centre of rotation is generally located in a more plantar direction, which reduces the ground contact surface area in the plantar portion of the foot (*Figure 5*).

Biomechanical basics of therapeutic farriery

Clinical decisions on therapeutic farriery should be tailored to the individual horse, following a full static and dynamic evaluation, an assessment of balance and an evaluation of the integrity of the hoof capsule. There are several principles that should be applied, to optimise hoof function and reduce abnormal or excessive stress, either as part of treatment of an established musculoskeletal injury or in the prevention of potential injury. The evidence-based biomechanical principles are (Oosterlinck et al, 2017):

- Optimising hoof balance
- Shock dampening during initial impact phase
- Appropriate slip/braking during the secondary impact phase
- Optimal pressure distribution during the support phase
- Optimising breakover
- Optimising hoof mechanism

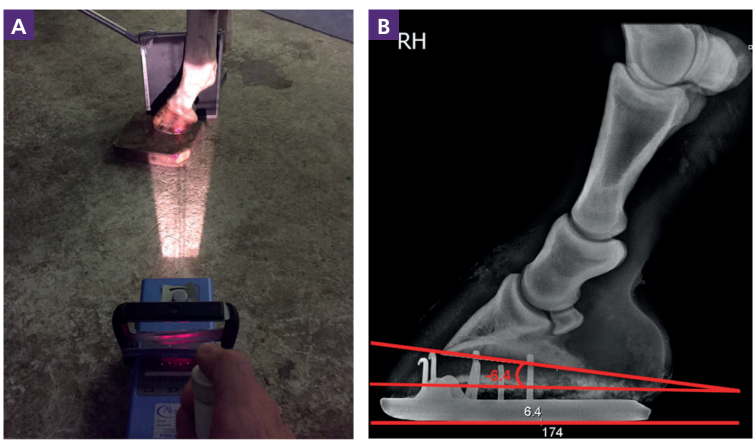

Figure 4: (A) Lateral hind foot radiographs are collimated to include the distal aspect of the metatarsus. (B) Lateral radiograph centred on the centre of rotation of the distal interphalangeal joint showing a negative plantar angle of -6.4° (red line) and increased solar depth at the toe.

Figure 5: Lateromedial radiograph of a left hind foot with low heel conformation. The centre of rotation is located in a more plantar direction (line) with a reduced ground contact surface area in the plantar portion of the foot.

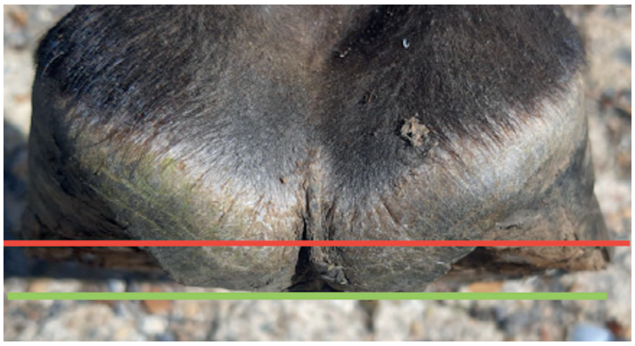

Figure 6: Plantar view of the foot showing prolapse of the frog (green line) distal to the heels (red line).

Farriery principles for low heels in the hind feet

Where the hoof capsule has migrated dorsally, the frog may displace plantarly and protrude or prolapse below the ground surface of the foot (*Figure* 6). The object of farriery here is to reduce the amount of frog below the ground surface of the foot and return the plantar region of the foot to a 'load sharing' function, thus optimising caudal support. In the first instance, the hoof wall at the heels, that has already exceeded its elastic modulus and collapsed, should be removed. The heels are trimmed with a rasp alongside the frog, instead of across the plantar half of the foot, to return the heels to a more plantar location (*Figure 7*). After this, assuming positive morphology, the heels should be left well alone on subsequent shoeings, unless they have re-collapsed.

There are different mechanisms to return the frog to a load-sharing plane and this will depend on the severity of the prolapse (O'Grady et al, 2018). If changes are mild, the shoes can be removed and the horse housed on a firm surface. This places pressure directly on the frog, which can assume the same plane as the heels very quickly. A wooden shoe can also be applied briefly and quickly, to put the heels and frog on the same plane. If the changes are more moderate and time is not of the essence, this method can still be effective by keeping the horse barefoot on a firm surface for a longer period and with a walking programme, until the frog is reduced to the same plane as the hoof wall. The heels are trimmed at 10-day intervals until the plantar foot is load sharing, which can take up to 6–8 weeks. Excessive dorsal hoof wall is removed from toe quarter to toe quarter. The sole at the toe should be reduced gradually over several shoeing intervals, as the depth of sole at the toe can be misleading on radiographs. Attempting to reduce the toe height quickly with overzealous trimming of the toe may intrude on the sole wall junction.

If the frog prolapse is severe, or if the horse needs to continue in work and be shod, a couple of days before a shoeing is due the hind shoes can be removed and trimmed as above and a frog plate can be attached to the foot. The foot is then soaked and poulticed and placed on firm ground for 2 days. The frog will soften and get compressed between the heels, forming an even load-sharing plane. The horse can then be shod, with meticulous consideration being given to the trim. The heels should be returned to as plantar a location as possible, alongside the base of the frog. Rasping across the heels and frog will ensure an even load-sharing plane. The difference between the centre of rotation of the coffin joint and

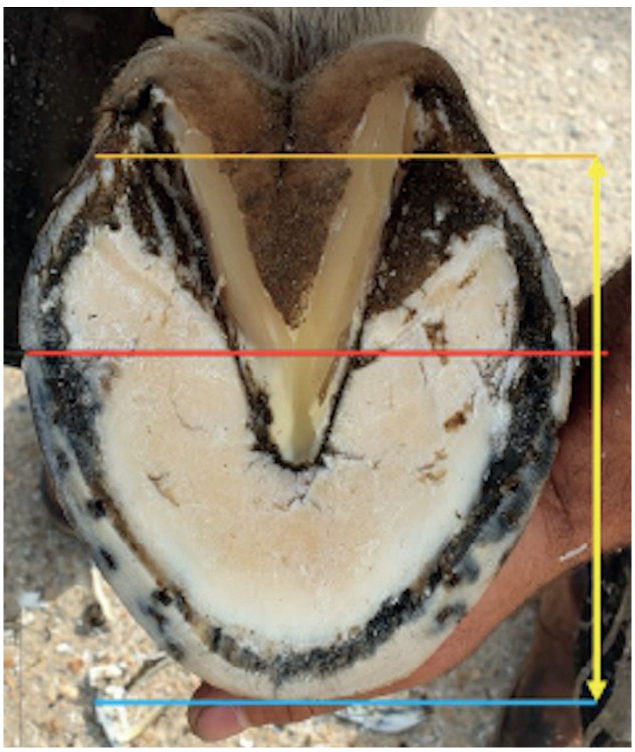

Figure 7: The heels are trimmed as far plantar as possible to return them to the base of the frog. In this scenario, notice how restoring solar proportions may not be enough and there are not approximate proportions dorsal and plantar to the centre of rotation.

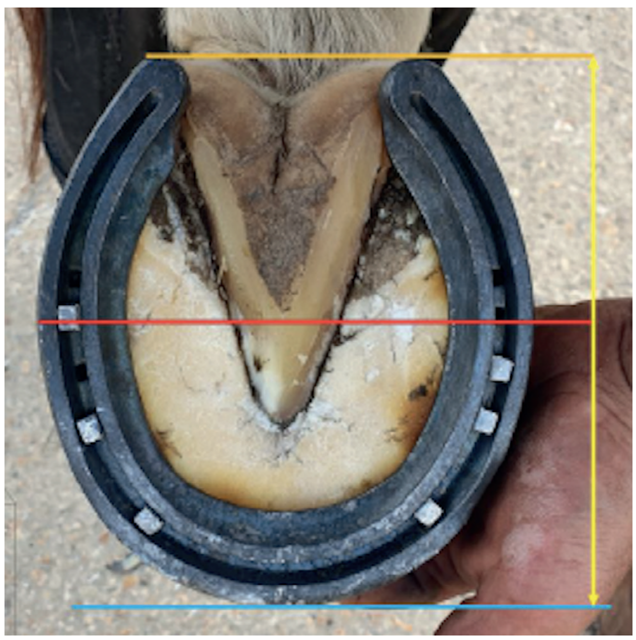

Figure 8: Shoe applied with the middle of the shoe on the line across the widest part of the foot. Notice the increased plantar length of the shoe to increase ground surface plantar to the centre of rotation.

Figure 9: (A) Horse with long toe low heel conformation, shod with a flat shoe. Note the negative plantar angle. (B) 5° Duo Ellipse shoe. (C) 5° Wedge. (D) 3° Duo Ellipse shoe. (E) Flat shoe with restored hoof-pastern axis improving posture and conformation, but the plantar heel angle still requires work.

the widest part of the foot can be verified on the hind foot radiographs. When the foot is shod, a line should be drawn across the widest part of the foot and placed in the middle of the shoe. The widest part of the foot in the hind feet is more plantar to that of the forefeet. Therefore, to get the required proportions of ground contact surface either side of the centre of rotation, an additional length of shoe is required. This tends to mean the branches of the shoe extend plantarly, to be in line with a vertical line down from the bulbs of the heel (*Figure 8*). Using a shoe with a frog or heel plate, which puts direct pressure on the frog, will decrease its size and allow it to assume a better position. The use of a recessed frog support wedge pad will more often than not result in a single load sharing plane of the heels and frog, without a disruption in routine. However, this does not always mean they no longer have an negative palmar/plantar angle.

Creating an ideal alignment and providing caudal support changes the posture of the horse and this is a contributing factor to a positive morphology of the hoof (*Figure 9*). The use of heel elevation to restore more optimal plantar angles divides opinion among farriers and veterinarians. Heel elevation will tend to exaggerate a heel-first landing and thus increase the pressure exerted on the hind feet, that already have low or underrun heels, further compromising the structures of the hoof capsule. Application of wedge creates a shift of the centre of pressure towards the side of the elevation (Wilson et al, 1998). Similarly, an egg-bar shoe moves the centre of pressure palmar/plantarly as they prevent the sinking of the heels into the ground (Chateau et al, 2006), resembling the biomechanical effects of a heel wedge on a hard surface.

If heel elevation is required, a leather wedge pad fitted, following the trimming principles previously described, will avoid further damage to the plantar aspect of the hoof capsule. Leather pads may be abrasive to weak heels, so if used, they should probably have a frog piece. Ample frog support should be given in any elevation, as wedge pads that do not have frog pieces will often still buckle under the horse's weight and not sufficiently support the foot. The heel wedge should be placed under the shoe at the heels, not behind the heels. This will concentrate the load across the load-sharing heels and the base of the frog. Although wedges have been shown to increase load on the heels, if supported by the frog this increase is well mitigated. The use of pads or wedges will also prevent the frog from descending distally between the

Figure 10: Duo Ellipse shoe is theorised to channel the point of ground force reaction to the centre of the foot, reducing the impact on the heels.

branches of the shoe towards the ground. This method of shoeing can be continued until the heels have stabilised. A wedge shoe also decreases breakover duration, compared with a normal, plain shoe or with an egg-bar shoe (Rogers and Back, 2007). Logically, this may reduce the strain on the more proximal hindlimb structures.

For horses that are able to enter into a rehabilitation period, shoeing with elevated Duo Ellipse hinds (*Figure 10*) is theorised to channel the point of force into the centre of the foot, de-loading the heels. Anecdotal reports on this method of shoeing suggest significant improvements in hoof morphology and conformation.

Conclusions

Long-toe low-heel conformation is the most common hindlimb hoof abnormality seen in clinical practice. Negative palmar/plantar angles have an important causal relationship to more proximal hindlimb lameness, thus lateral radiographs should be taken to quantify dorsoplantar hoof imbalance in horses with hindlimb lameness. Appropriate farriery to address these hindlimb hoof abnormalities is essential and requires a professional working relationship between the veterinarian and farrier. The principal aims of farriery are to return the plantar half of the foot to a load-sharing plane between the heels and the frog, optimising caudal support and restoring optimal phalangeal alignment. Therapeutic farriery interventions should be specifically tailored to the individual horse, with an emphasis on monitoring the progression of positive hoof morphology following any intervention. The precise intervention is based on several factors including, but not limited to, the horse's orthopaedic injuries, rehabilitation schedule, hoof morphology, posture, radiographic findings and the personal experiences of both the treating veterinarian and farrier. EQ

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Conflicts of interest

The author declares no conflicts of interest.

KEY POINTS

- Long-toe, low-heel conformation with a broken-back hoof-pastern axis is the most common hoof abnormality seen in the hind feet.
- Low-heel conformation with a negative plantar pedal bone has been shown to have a causal relationship with more proximal hindlimb lameness.
- Hoof conformation can be accurately assessed with a thorough clinical, physical and dynamic examination.
- Radiography of the hind feet is very helpful, because it quantifies the conformational abnormalities and assists the vet and farriery with taking an appropriate intervention.
- Therapeutic farriery is required to restore positive hoof morphology and is an essential part of a holistic approach to treating horses with hindlimb lameness.

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