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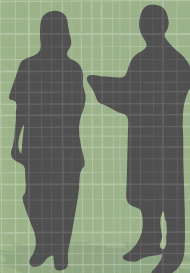
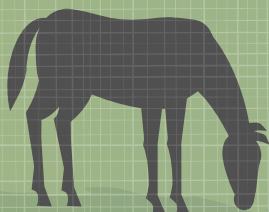
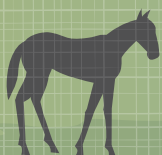
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Negative plane of the distal phalanx – pathogenesis and management

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The negative plane of the distal phalanx (DP) visualised radiographically is a clinical sign, not the problem. The problem(s) are related to either an injured structure that caused this angulation, or to stresses on structures caused by the change in conformation. The relationship between the DP solar border and ground is related to the angulation of the distal interphalangeal joint (DIPJ); as such, the negative plane of the distal phalanx represents dorsiflexion of the DIPJ. The majority of studies have examined the relationship between hoof angulation, ground reaction force (GRF) and tension in the deep digital flexor tendon (DDFT) in short-term studies of front feet of healthy horses, so the front feet will be the focus of this discussion.

Dorsiflexion of the DIPJ is usually associated with low/underrun heels and broken back foot–pastern axes and is essentially the opposite of a flexural deformity (club foot); however, occasionally the foot–pastern axis does not appear broken back if the angle of the pastern is low. The degree of flexion or dorsiflexion (extension) is determined by the balance of the extensor and flexor moments about the joint. The flexor moment is the product of the tension in the DDFT and the shortest distance from the centre of rotation to the DDFT (flexor moment arm); of these, the flexor moment arm is fixed, but the DDFT tension is variable. The extensor moment is the product of the GRF and the shortest distance from the line of action of the GRF to the centre of rotation of the DIPJ (extensor moment arm (EMA)); of these, the weight borne by the limb is relatively constant at rest, but the length of the EMA is more variable. The length of the EMA is dependent on the location of the GRF point of action called the centre of pressure (COP). At rest, the COP is approximately in the centre of the ground surface and dorsal to the centre of rotation of the DIPJ. A reduction in the DDFT tension or increase in the EMA will create a tendency for the DIPJ to dorsiflex. However, under natural circumstances on flat ground, the length of the EMA almost always passively follows a change in DDFT tension; as such, an increase in the EMA is usually secondary to an increase in tendon tension associated with a club foot, not dorsiflexion of the DIPJ. As well as determining the DIPJ angle, the equilibrium between the extensor and flexor moments strongly influences the height and angulation of the hoof wall at the toe and heels. In turn, height and angulation of the toe and heels influence the biomechanics of the foot.

As well as focusing on healthy feet, most studies have assumed that the DP and hoof capsule function as a single entity. However, while the DP is a rigid structure that changes slowly, the hoof grows continuously, exhibits viscoelasticity, and changes shape relatively rapidly. As such, when the load on the heels exceeds their ability to withstand it they collapse, i.e. increased load and/or decreased structural integrity. Increased load associated with a type of exercise, and/or ground surface with 'normal' conformation and joint mechanics, can cause the heels to collapse. However, more commonly either allowing the hoof to grow too long causes the heels to migrate dorsally towards the COP or extending the heels with a shoe moves the COP towards the heels, either of which will increase the stress on the heels. Additionally, elevating the heels shortens the DDFT

which decreases the flexor moment, while at the same time moving the COP closer to the centre of the rotation, which will increase the load on the heels. If dorsiflexion of the DIPJ and underrun heels is allowed to persist, it may result in permanent damage to structures of the palmar foot. Additionally, it may lengthen the DDFT though this is not documented. Together these result in a new equilibrium.

Management

Conformation changes secondary to a primary injury require therapy directed at the injured structure. Short-term changes in conformation secondary to an imbalance between the integrity of the heels and the load can potentially be reversed. Long-standing changes in conformation with secondary structural damage changes usually requires palliative management.

From a biomechanical perspective the logical approach would be to increase the flexor moment by increasing the tension in the DDFT (and associated accessory ligament) or decrease the extensor moment by decreasing the EMA. Unfortunately, the former is not currently feasible, and the ability to actively change the latter is extremely limited even if possible; it usually changes passively in response to changes in DDFT tension. Regardless, moving the COP in a palmar direction has untoward consequences for the structure of the heels.

For horses with changes of short duration and time permitting, a barefoot trim that includes removing all underrun heels and trimming the toe back/shortening breakover is probably the best option for restoring an upright conformation with improved heel structure.

For horses with changes of longer duration, palliative management is directed at trimming the heels and shortening the breakover as previously described and using shoes/pads to realign the phalangeal axis and the solar margin of the distal DP with the ground. This is most readily accomplished by heel elevation with a wedge shoe/pad but can also be achieved by extending the heels with a shoe which functions as a wedge on a deformable surface. Both risk further heel deformation. Therefore, it is preferable to recruit all the structures in the palmar half of the foot to bear weight, whether the heels are elevated or not.

Conclusion

It is preferable to discontinue referring to the plane of the DP as a diagnosis and instead refer to the angle of the DIPJ which more accurately reflects the pathogenesis. There is no simple answer/one size fits all solution when presented with this conformation and prevention is preferred to management.

Further reading

- Clayton, H.M., Gray, S., Kaiser, L.J. and Bowker, R.M. (2011) Effects of barefoot trimming on hoof morphology. *Aust. Vet. J.* **89**, 305–311.
- Eliashar, E. (2012) The biomechanics of the equine foot as it pertains to farriery. *Vet. Clin. North Am. Equine Pract.* **28**, 283–291.
- Hunt, R.J. (2012) Farriery for the hoof with low or underrun heels. *Vet. Clin. North Am. Equine Pract.* **28**, 351–364.