New research calls into question current beliefs of foot function

I have questioned the simplicity of conventional foot function theory for much of the 25 years of my professional career. The treatment of the equine foot with little regard to the sensitive internal structures, and the role each play is irresponsible at best. To teach hoof care using anecdotal antiquated theory as a foundation, and then in some cases to label it as *Natural*, is ludicrous.

Today there are a great number of studies on the equine foot that could fall under the category of evidence based medicine; there are also several that do not. Sifting through the thousands of pages of text available on the equine foot did reveal one important fact; that a large percentage of today's hoof care professionals, whether labeled natural or traditional are comfortable, even complacent in their acceptance of the simplest of foot function theories.

My own anatomical studies and on-going research have revealed the importance of otherwise overlooked structures, vital to the proper function of the equine foot. I have gone so far as to develop theories that support the science of Energetics. Energetics defines a science that goes beyond simple bio-mechanics, and embraces physiology as a component of the whole.

The Suspension Theory of Hoof Dynamic™, Internal Arch Apparatus theory™, and my Hoof Growth theories will answer many of the questions facing today's researcher, horse owner, and hoof care professional. At the very least, these theories provide us with a starting point from which we may move ahead, this in contrast to the accepted simplistic explanations that provide us comfort in our current treatment of the equine foot.

What follows is a brief outline of my theories on energy management within the equine foot. It has been created to help reduce the anxiety of those who find themselves questioning the more vocal foot experts.

Energy Management within the Equine Foot (Foot function) **by KC La Pierre**

Close examination of the digital cushion and the relationship it holds with the lateral cartilages and surrounding tissue calls into question their functions. There are several theories that account for the function of the digital cushion-cartilage anatomy. The *depression theory* holds that pastern movement into the digital cushion during the impact phase of the stride causes the digital cushion to force the cartilages of the foot outward, aiding in circulation and energy management. The *pressure theory* utilizes ground (solar) contact, with the frog stay pushing upwards into the digital cushion forcing the lateral cartilages to move outward. Both theories speculate that the digital cushion and the vasculature that accompanies it play a role in energy management, with the digital cushion absorbing the energy.[1] Attempts to define haemodynamic function of the digital cushion have also suggested that during ground impact, the outward expansion of the cartilages of the foot occurs through the bars' contact with the axial projections of the cartilage, and the downward movement of the bony column into the digital cushion. When this occurs, it is hypothesized that venous blood within the vessels of the palmar aspect of the foot is forced into the micro venous vasculature within the vascular channels of the ungular cartilage of the foot. Hydraulic resistance to flow through the micro vasculature dissipates the high energy. It is thus hypothesized that foot haemodynamic action accounts for the negative pressure recorded at mid stance, stating that the negative pressure would allow for refilling of the vasculature before next foot fall.[1,2] It is further hypothesized that the negative pressure is the result of rapid outward movement of the cartilages of the foot.[2]

Research into those structures that join with the cartilages of the foot, and the digital cushion provide evidence that may contradict the pressure and depression theories and support several aspects of the *Suspension Theory of Hoof Dynamics™.*

Examination of those structures that may work in concert with the cartilages and digital cushion is necessary to formulate a working hypothesis for foot function. We also

[1] Bowker RM, New Theory may help avoid Navicular, News Release, March 1999, Mich. State University,

[2] Dyhre-Poulsen P, Smedgaard HH, Roed J, et al: Equine hoof function investigated by pressure transducers inside the hoof and accelerometers mounted on the first phalanx, *Equine Vet J* 26:362, 1994

need to look to areas that may have otherwise been over looked in previous attempts to understand foot function.

The *coronary band* and its attachment are very poorly defined, when compared to those of the ligaments, cartilage, and digital cushion of the foot. Its attachment to the ungular cartilages and extensor process could prove to be a vital piece of the puzzle in the search to define proper foot function.

The coronary band (Pulvinus coronae) lies in the coronary groove immediately distal to the periople corium, proximal to the parietal surface of the distal phalanx, and abaxial of the ungular cartilages of the foot.

In vitro studies of the coronary band suggest that its relationship to the ligaments of the foot and cartilages of the foot may play a significant role in haemodynamic flow.[3] The Suspension Theory of Hoof Dynamics™ hypothesis that during the ground impact phase, the pastern begins to descend, causing the lateral cartilages of the foot to move outward. This occurs as a result of ligament, fibrous and fascia attachment influences, and displacement caused by the second phalanx, as opposed to digital cushion displacement. The pressure exerted on the vasculature of the foot by the displacement of the cartilages by the distal palmar movement of P2, and the *resistance provided by the coronary band and its attachment* restrict venous blood flow.

[3] La Pierre KC, Lord RA, et al: Unpublished data. Coronary Band Functional Anatomy: a biomechanical study, 2006

The Suspension Theory of Hoof Dynamics™ further hypothesizes that just prior to mid stance, the pastern begins to ascend, this releasing venous blood now *under pressure*. This rapid exchange of blood *under pressure* from the ungular cartilage, and coronary vasculature to the proper palmar digital vein would result in a negative pressure in the foot. This action would presumably cause rejection of both the pressure, and depression theories, as well as dispel the concept that hoof expansion was responsible for finding negative pressure within the digital cushion at mid stance. The suspension theory redefines haemodynamic function, to include haemodynamic response.

The amount of resistance that the venous blood meets during the stance phase would depend upon several factors including, health of internal arch apparatus, pastern movement, and amount of force. The greater the force, the greater the pastern movement, the greater the resistance the coronary band would need to provide. The amount of pressure within the foot during the impact and stance phase will be in direct ratio to pastern movement, and the resistance to expansion provided by the cartilage, coronary band, and hoof capsule. It then becomes the amount of pressure, and the health of hoof capsule, connective tissue, ungular cartilages, and digital cushion that will determine haemodynamic response and energy utilization. All directional movement of the ungular cartilages, coupled with distal palmar movement of P2 would result in a variable restriction of blood flow proximally from the foot. It is likely that medial-lateral and proximal-distal movement of the palmar axial projection of the lateral cartilages would be influential in the timing, and the ratio of force to pressure occurring during the impact and stance phases of the stride.[4] It can easily be understood why the coronary band has been overlooked as an important component in energy management, with the coronary band being commonly viewed as elastic in nature.[5,6,7]

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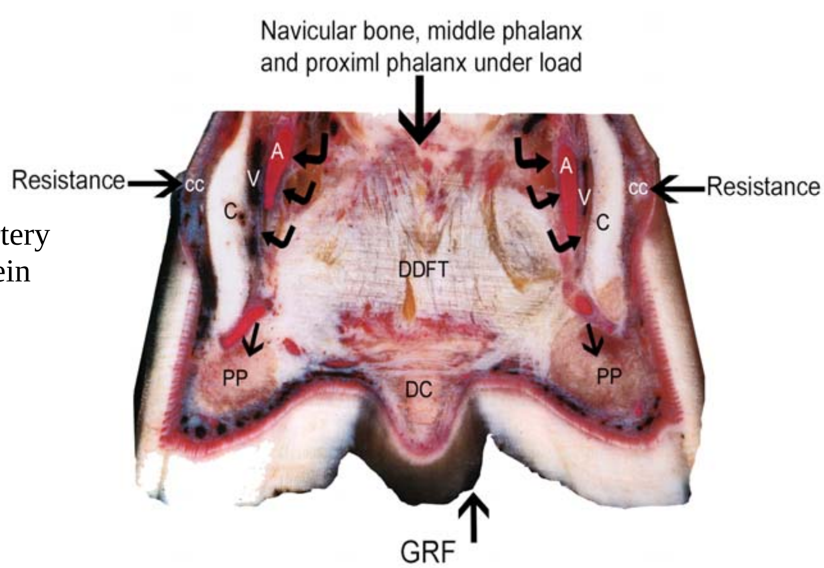
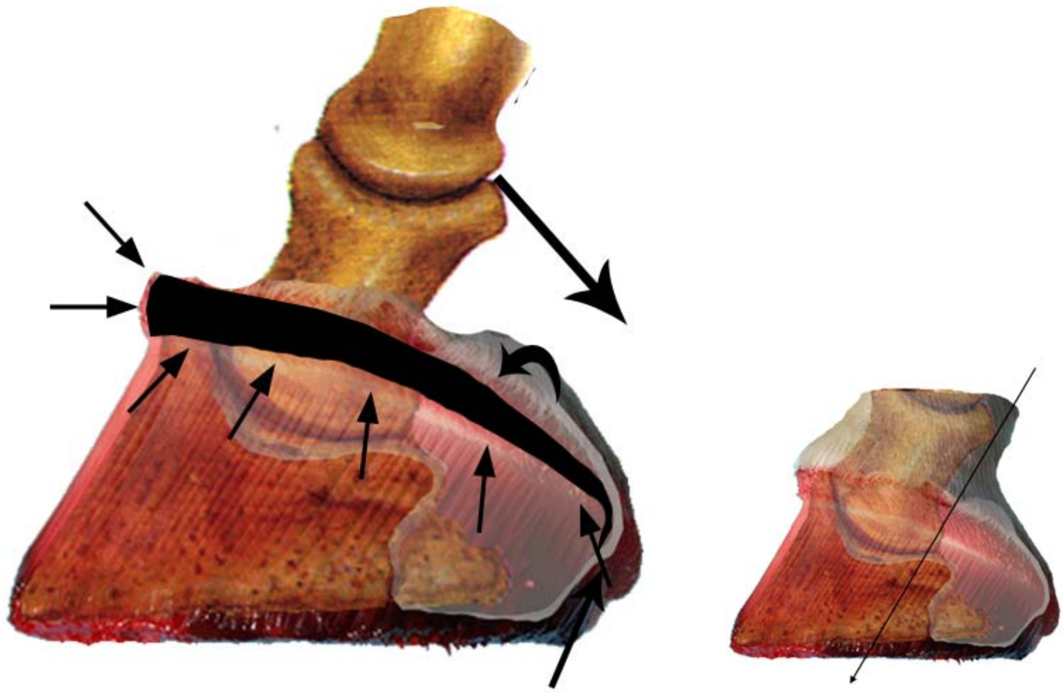
[4] Denoix JM, The Equine Distal Limb, An Atlas of Clinical Anatomy and Comparative Imaging, ed 4th, 2005, London, Manson Publishing Ltd.
[5] Butler D, Butler KD, The Principles of Horseshoeing, 3rd ed, pg 219, Doug Butler Enterprises, Co. 2004
[6] Dollar AW, The elastic tissues of the foot, In: A handbook of horse shoeing, New York: Jenkins Veterinary Publisher & Bookseller, 1898;15-16
[7] Egerbacher M, Helmreich H, et al, Digital cushions in horses comprise coarse connective tissue, myxoid tissue, and cartilage but only little unilocular fat tissue, Anat, Histol, Embryol, Vol.34, 2:112, 2005

Figure 1 illustrates the function defined by the relationship of the coronary band (Pulvinus coronae) to that of the vasculature of the proximal palmar aspect of the foot, upon impact. The anatomical evidence pictured supports the *Suspension Theory of Hoof Dynamics*™. In the transverse section illustrated, the digital cushion would have little effect on the mechanisms described by the STHD. Anatomical evidence does support the hypothesis of a *functional internal arch apparatus*, where all structures work in concert to regulate haemodynamic flow, haemodynamic response, and energy management. This hypothesis would seem to negate the simplistic belief that the frog's primary function is to pump blood, or to act as a vehicle for the necessary displacement of the digital cushion, as outlined in the pressure, and depression theories. The STHD defines the angle of the bar/wall as the primary instigator of pastern movement upon impact, and would explain why performance horses are capable of dealing with the energies created at speed, with less than healthy frogs. Injury appears to occur more often in the foot with poor conformation of heels, than in those that have unhealthy frogs, although unhealthy frogs often accompany poor heel conformation. Whereas shoeing will support the depression, pressure and haemodynamic theories, it will not support the STHD. The depression, pressure, haemodynamic theories require only expansion and contraction of the palmar aspect of the foot, where the suspension theory requires three dimensional distortion of the cartilages and palmar aspect of the foot.

Figure 1

A. Proper palmar digital artery
V. Proper palmar digital vein
C. Ungular cartilage
CC. Pulvinus coronae
PP. Palmar processes
DC. Digital cushion

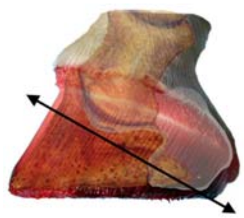




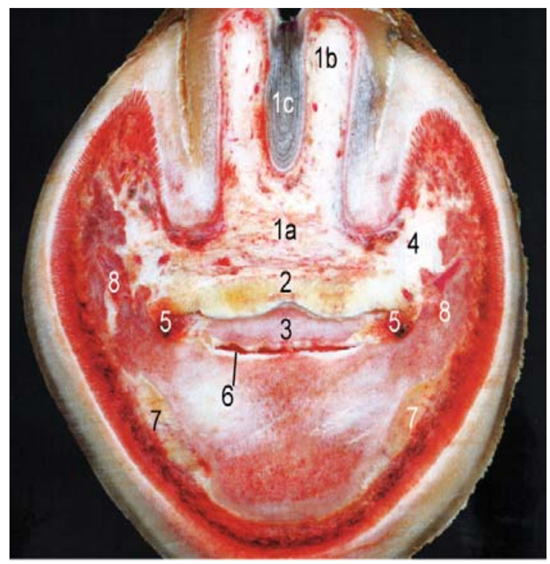
Timing is crucial to proper function, with timing being determined by pastern movement. Pastern movement is determined by the balance of the hoof capsule around the axis of the foot, and placement of the distal most surface of the angle of the bar/wall. **(Above)** Position of heel purchase is defined by the conformation of the cartilages.

Digital Cushion

The digital cushion consists of fibrous, cartilaginous tissue, course connective tissue, and elastic tissue. One study suggests that the digital cushion contains myxoid tissue. Myxoid tissue is known to continuously transform into loosely organized coarse connective tissue. It is said that the digital cushion of the hind foot contains a greater amount of adipose and elastic tissue, this likely due to the greater weight-bearing capacity of the forelimb. Recent studies suggest however that the digital cushion has little unilocular fat tissue.[8] If in fact there is myxoid tissue throughout the digital cushion, then it is reasonable to believe that its health can be improved with the application of proper stimulus.



1. Digital Cushion
    - 1a. toric part
    - 1b. cuneal part
    - 1c. frog spine
2. Deep digital flexor tendon
3. Distal sesamoid bone
4. Ungular cartilage
5. Proper palmar digital artery and vein
6. Distal interphalangeal joint (distopalmar recess)
7. Collateral ligaments of the DIP joint
8. Palmar processes



Debate as to the function of the digital cushion continues. Recent studies indicate that its biomechanical function is to act as a restraint to the displacement of the second phalanx, or as a passive structure that allows for flexibility of the caudal two thirds of the foot.[9] It is suggested that displacement of the digital cushion is independent of solar support.
The sensitive frog (corium) has its deep surface apposed to the digital cushion, with its conformation and foundation being the digital cushion. There are few veterinary references to the actual function of the sensitive frog. Research has been conducted on the importance of propioceptors within the area of the digital cushion that represents the sensitive frog, though little conclusive evidence exist in support of the sensitive frog/digital cushion being responsible for determining stride.[10] Following the hypothesis that frog health represents digital cushion health, it becomes difficult to support the

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[8] Egerbacher M, Helmreich H, et al, Digital cushions in horses comprise coarse connective tissue, myxoid tissue, and cartilage but only little unilocular fat tissue, Anat, Histol, Embryol, Vol.34, 2:112, 2005
[9] Taylor DD, Hood DM, Potter GD, Hogan HA, Honnas CM, Evaluation of the displacement of the digital cushion in response to vertical loading in the equine forelimbs, Am J Vet Res 66:623-629, 2005
[10] Bowker RM, Brewer KB, et al: Sensory receptors in the equine foot, Am J Vet Res, 54: 1840-1844, 1993

theories that utilize the frog and digital cushion as the primary structures responsible for aiding circulation within the equine foot. This statement is in response to the hundreds of thousands of horses that perform at high levels of competition while exhibiting signs of a unhealthy digital cushion.

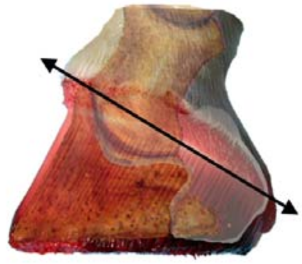
The suspension theory defines the frog/digital cushion as a vehicle of stimulus, aiding in the distribution of pressures within the caudal aspect of the foot. Further investigation of several studies conducted on the function of the digital cushion support this hypothesis.

Ungular Cartilages (lateral cartilages)

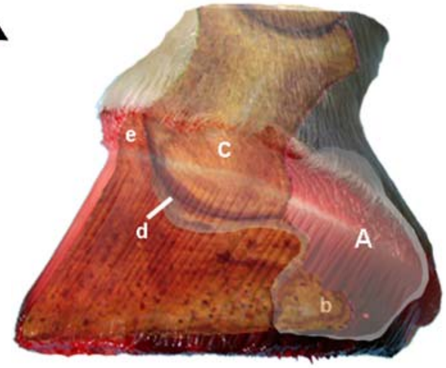
The cartilages of the distal phalanx attach along the proximal palmar surfaces of the palmar processes, with this attachment running dorsal-proximal along the proximal edge of the distal phalanx to the medial and lateral borders of the extensor process, and abaxially medial and lateral of the semi lunar line. From their attachment to the distal phalanx, the cartilages along with several other structures function to support the foot and limb of the horse, as well as being an integral part of the energy management mechanism present within each limb.[11] The cartilages of the foot originate as hyaline-type cartilage and become fibrocartilage in adult horses. The morphological features of the cartilages of the distal phalanx vary greatly with a range of shapes and thicknesses. Variations in axial projection from its distal edge and in vascularity exist from specimen to specimen; there is a marked difference in the thickness of the front foot to that of the hind foot.[1] In addition to support and energy dissipation, the cartilages of the foot support the function of energy utilization.

Cartilage conformation holds influence over the efficiency of energy utilization and energy dissipation within the equine foot. The angle of the palmar abaxial and axial projections of ungular cartilage distal to the palmar attachment of the coronary band determines how the energies of impact are received by the internal arch apparatus. The corium supported by the abaxial/axial palmar projections of the ungular cartilages produce the epidermal laminae of the heel and bar, white line of the bar and angle of the wall, inner layer of hoof wall of the bar and heel, and horny sole at the seat of the corn. The coronary corium produces the outer wall of the heel and bars. The angle of the wall/bar (ground surface of the heel) being the primary epidermal structure that transmits the energies created during the impact phase along a proximal-palmar plane of attachment, to the ungular cartilages.

[11] Clayton HM, Flood PF, Rosenstein DS, Clinical Anatomy of the Horse, 2005, Mosby Elsevier, Edinburg

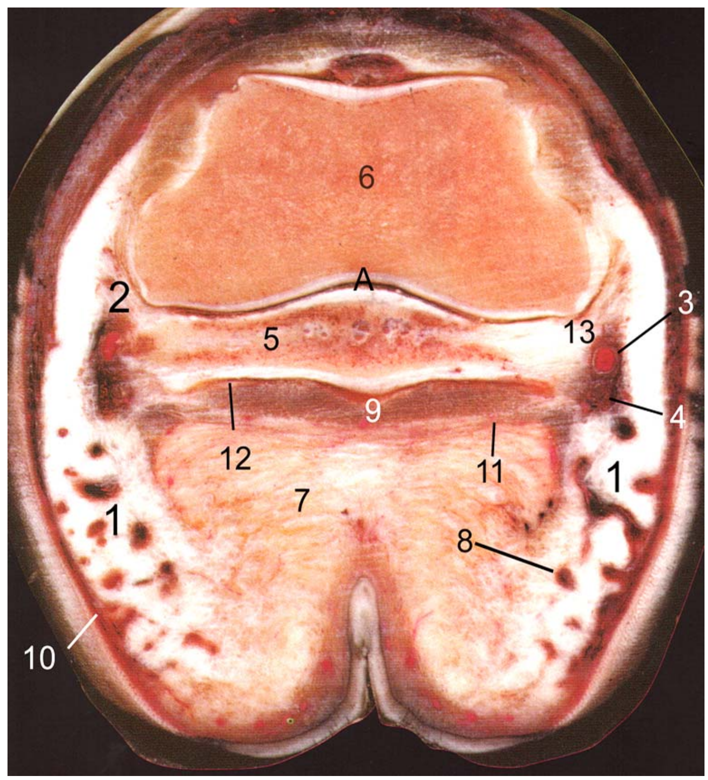


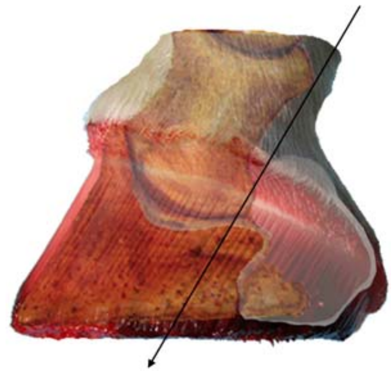
A. **Ungular cartilages**
b. Palmar process
C. Coronary band
d. Distal interphalangeal (DIP) joint
e. Extensor process



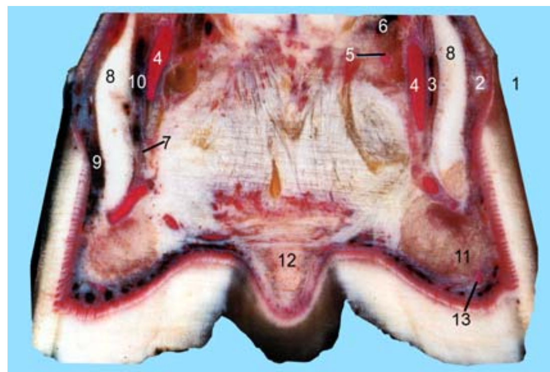
1. **Ungular cartilage**
2. Chondrosesamoidean ligament
3. **Proper palmar digital artery**
4. **Proper palmar digital nerve**
5. Distal sesamoid bone
6. Middle phalanx
7. Digital cushion
8. **Deep ungular plexus**
9. Deep digital flexor tendon
10. Corium coronae
11. Distal digital annular ligament
12. Flexor surface
13. Collateral sesamoidean ligament

A. Distal Interphalangeal joint





1. Corium coronae
2. ***Pulvinus coronae***
3. ***Proper palmar digital vein***
4. ***Proper palmar digital artery***
5. Palmar artery of the middle phalanx
6. Palmar vein of the middle phalanx
7. Proper palmar digital nerve
8. **Ungular cartilage**
9. ***Superficial ungular plexus***
10. ***Deep ungular plexus***
11. Palmar process of P3
12. Digital cushion (cuneal part)
13. Circumflex artery



For more information about the Suspension Theory of Hoof Dynamics™, and the Internal Arch Apparatus theory™, visit www.appliedequinepodiaty.org