The Biomechanics of Toes & Nails

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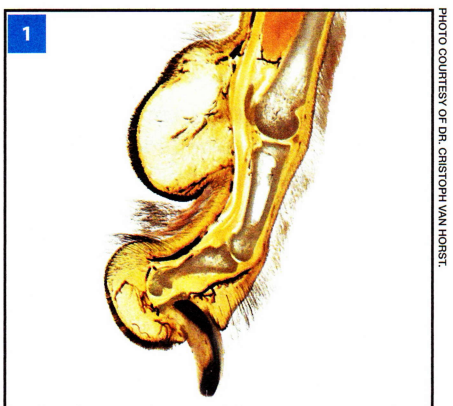
"No foot, no horse" is a saying in the horse performance world. But why doesn't anyone say, "no foot, no dog?" It is amazing to me that the importance of the biomechanics of the foot—how it lands, handles differences in terrain, absorbs load and then generates movement forward—seems to be skipped over in the performance canine world, yet the foot is no less critical to the dog than it is to the horse or human. Any one who has ever stubbed their toe or gotten a blister can attest to how quickly a little problem can begin to interfere with the fluidly moving interface of the foot and toes with the ground.

Often in performance dogs, lameness exams focus on shoulders, elbows, hips, and knees, completely forgetting those tiny little digits. Despite the enormous use of dogs in sport and work, and the money invested in those activities and training, there is little research on the biomechanical changes that can occur to normal gait from differences in nail length, arthritis, soft tissue injuries, the presence of booties, etc. According to a study published in the *Journal of the American Veterinary Medical Association* in 2013 (Cullen, 2013), "sprains, strains and contusions of the shoulder, back, phalanges (toes), and neck" were the most common injuries to occur to agility dogs. Because of the size of the bones and soft tissues of canine toes, many injuries are difficult to treat and painful to the dog. Many toe injuries can be career ending, making prevention and early identification of problems even that much more important in the dog.

Anatomy

There is little soft tissue in the canine digit, but what is there plays a critical role in maintaining foot shape and function. See **Figure 1.** The bones of the canine digit are not aligned straight and flat as they are in the human. Rather they are sandwiched in a delicate, bent balance of elasticity between extensor and flexor tendons. See **Figure 2.** There are also paired dorsal ligaments that attach between the end of the middle toe bone (phalanx) and the beginning of the last phalanx (encased by the nail) that act to keep the nail pulled up off the ground. The nail makes contact with the ground only during movement when the pull on the flexor tendon is enough to overcome the resistance of the dorsal ligaments.



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A photo of a dog's toe prepared in resin that is then sliced thinly to demonstrate anatomic and tissue detail as a light shines through it. Note the "bend" of the digit caused by tension of the flexor tendons. The two flexor tendons can be identified between the first and second phalanges (bones) of the toe.

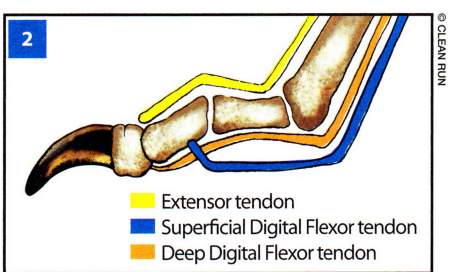


Diagram of the canine digit showing the relationship of bones to tendons

Sadly, there is no research to date looking at the actual biomechanics of the canine digit, but basic biomechanics dictates that anytime small, rigid structures (like the phalanges or toe bones) are held together in angled positions by elastic structures (tendons), energy is able to be absorbed then retransmitted through that structure. This is done via a careful balance of tension between the tendon that extends the toe (the digital extensor tendon) and the two tendons that flex the toes. These two tendons are called the superficial digital flexor tendon (which attaches in the middle phalanx or toe bone) and the deep digital flexor tendon (which attaches to the last digit bone which is encased by the nail). The two flexor tendons not only flex the toe and straighten the foot, but they also resist the extension and collapse that happens when the foot strikes the ground and suddenly comes to a stop. They also assist in the rebound as the foot then pushes off the ground to start a new cycle of motion. The flexor tendons act as springs to return the bend of the digit after the foot is flattened by the forces of the animal's weight loading against the ground.

The opposing ends of the joints are held together by the two collateral ligaments (medial and lateral). The elasticity of these ligaments helps to hold the joint together side to side and absorb the small shifts of the joint surfaces as they slide along each other when the foot strikes the ground. In a full dislocation, one or both of these ligaments is usually fully ruptured. These injuries will heal, but the joint now moves with asymmetric laxity that eventually leads to arthritis.

In many of the toe joints there are small sesamoid bones. These bones are usually paired and present either above the joint or below it. Numbers and presence can vary among individual dogs. Sesamoids occur wherever a tendon has to make a sharp bend and they help to deflect the concentration of forces that the change of direction places on the tendon. In the dog, these digit sesamoids are embedded in fibrocartilage.

Digital Soft Tissue Injuries

When a performance dog dislocates or breaks a toe bone in a sudden traumatic event, it is pretty easy to diagnose. There is usually quite a bit of pain and swelling associated with those type of bony injuries. Not only do most dogs definitively tell a palpating veterinarian or handler there is something wrong (although not always), but the injury is also easy to identify with an x-ray. But what about the subtle soft tissue injuries that come from repetitive stress? These can be much more difficult to identify as a source of poor performance or inconsistent lameness, especially in a high-drive dog with a high pain tolerance.

Injuries to the flexor tendons can easily happen when a dog is moving over anything on the ground which is sharp. A full cut that goes completely through the skin can involve the tendon or tendon sheath, leading to loss of the flexor "spring." Besides the presence of an obvious laceration, the loss of the pull of a bisected tendon will result in a flattening of the toe bend and a toe that will stick out longer than the other toes of the foot. See **Figure 3.** What is easily forgotten is that tendons can also fail slowly over time due to excessive load and stress. Without an obvious injury like a laceration to make a dog's caretaker pay close attention to the shape of the foot and length of toes, slowly developing tendon laxity is often missed until it starts to interfere with performance or movement.

A dog foot demonstrating rupture of the flexor tendon of the toe second from the right. Note how the toe is slightly rotated and the nail sticks out longer than the toe to its left.

Chronic sesamoiditis is also a problem in some competitive dogs. It was first reported to be a problem in Labrador Retrievers competing in field trials. It can be so serious that one proposed method of addressing it is removal of all the small sesamoids of the foot. While there might be genetic factors at play with some of these cases, any forces that stress the flexor tendons will also affect the sesamoids.

Constant jamming of the digits can cause sudden rotational, lateral, and shearing *forces at the joint.* These forces always cause a slight displacement of the joint surfaces against each other. Taken as a one-time event, the elasticity of the collateral ligament is designed to handle these forces. However, over time, constant loading by both normally and abnormally-oriented forces will break down individual collateral ligament fibers. This creates gradual laxity of the joint which results in cartilage damage, loss and arthritis. See **Figure 4.** An example of these kinds of injuries is the digital arthritis that is commonly seen in dogs that work on slatted A-frames.

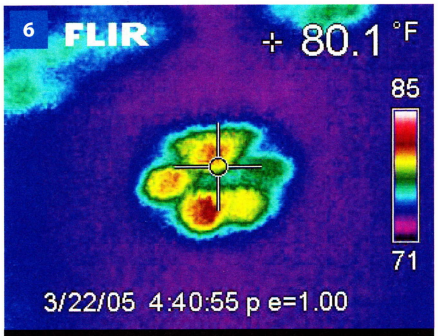
The foot of this agility Golden Retriever shows toe deviation that is typical for long-term damage to collateral ligaments. Both of the outside toes are slightly deviated, but the one on the left is altered enough that it is also affecting how the nail is worn.

Note the differences between the two feet because of nail length. The foot on the left has all but one of the nails trimmed to have adequate ground clearance at rest. The foot on the right has nails that are long and touching the ground. Note the difference in the width and shape between the two feet. The foot with the shorter nails is narrower and the knuckles are higher (thus more elastic spring of the flexor tendons). The foot with the longer nails is wider and flatter indicating that, even at rest, there is loss of tension and function of the flexor tendons.

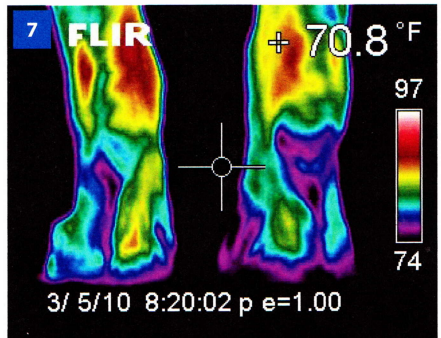
The Role Of The Nail

There is controversy among agility handlers whether it's better to cut nails short to prevent excessive leverage on the end of the toe or to leave the nail longer to assist in grip and traction as a dog moves over uneven terrain like dirt and grass. It makes biomechanical sense that any stress that excessively makes the flexor tendons stretch and retract, stretch and retract will eventually weaken them over time. A longer nail that actually touches the ground when the foot is neutral and standing (remember those dorsal ligaments retract the toe off the ground until the flexors engage) will increase the amount of stretch and therefore the stresses put on the digit. On the other hand, nails that are too short will never touch the ground no matter how much the flexor tendons contract trying to get them there. This could lead to muscle fatigue and significant injuries as the dog tries to maintain traction on slippery terrain and overstress to other tissues (such as the iliopsoas muscle) trying to compensate for the loss of traction. See **Figure 5.**

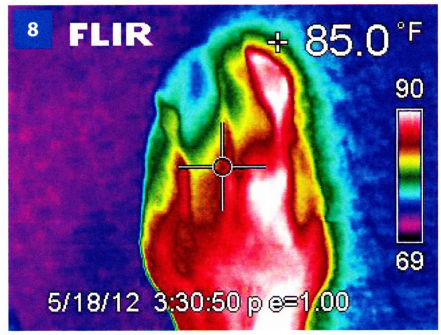
Sadly there is no research to date to answer this important question. The ideal nail length is probably somewhere in the middle, where the nail is short enough to be retracted off the ground in a neutral

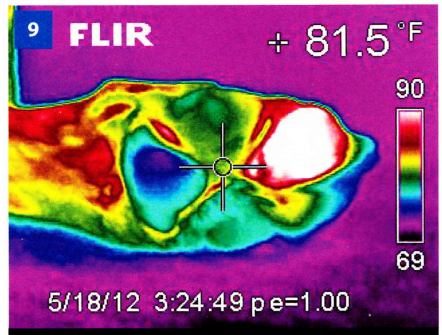


This is a thermal image of a paw print left on the floor by a foot with severe arthritis of a digit. Notice how the pad on the left center is warmer (red) than the others and the one on the far right is cooler.



This is a thermal image of the back of a sled dog's front feet. The flexor tendon to the third toe on the left front foot is significantly warmer than its equivalent on the other foot. The carpus (wrist) on the same foot is also warmer, possibly due to compensation from the toe. The only symptom the dog displayed was a little discomfort when both the wrist and the toes were palpated and flexed.





These images are thermal views of the top and bottom of the hind foot of a markedly lame dog that had been diagnosed as having a cranial cruciate ligament tear. The feet had not been examined. A physical exam determined that the CCL was normal and thermal imaging found marked heat (white area) in a toe. X-rays revealed a small chip fracture, probably from being stepped on.

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standing position, but long enough that moderate contracture of the flexors during motion can get those nails into the ground when they are needed for traction. No doubt the wild canine is moving constantly on abrasive terrain that will wear the nail down to the perfect length. But in the domestic performance dog, the human has to make the decision on length.

Evaluating Toe Health

So what is an agility handler to do? Act proactively. Don't just check your dog's nails, but look at foot shape, width, and conformation as well. Trim nails on a regular basis. Palpate individual toes from the nail to the metacarpals/metatarsals (the bones equivalent to the human palm or foot). Feel for the small changes. I encourage my clients and interns who want to better examine their dog's feet to close their eyes and softly feel along the digit from nail to metacarpals until they can identify all the normal structures. This can accomplish a couple of things. First, it will allow a handler to know what is normal so abnormal is more easily recognized (and earlier if toes are examined regularly). Second, many clients have reported that their dogs become better about having their feet handled. If done gently, the palpation is much like massage on an area of the body that is rich with nerve endings.

Last, but not least, if you happen to be lucky enough to have a veterinarian with a thermal imaging camera, have your competitive dog's toes regularly scanned from above, below, and from the sides. If the dog is standing on a smooth surface, the paw print can also provide clues that a toe imbalance is occurring. See **Figure 6.** Often thermography can detect subtle deviations from normal tissue temperature that can precede lameness. See **Figure 7.** In acute lameness that can be hard to localize in the foot, the detail of thermal imaging can quickly identify where circulation has deviated from normal thus providing guidance for further diagnostics and exam. See **Figures 8 and 9.**

References

Cullen KL, Dickey JP, Bent LR, et al. Internet-based survey of the nature and perceived causes of injury to dogs participating in agility training and competition events. J Am Vet Med Assoc *2013: 242: 1010-1018.*

After receiving her veterinary degree from Purdue University in 1986, Dr. Henneman completed certification in veterinary acupuncture (IVAS) in 1991 and veterinary chiropractic (AVCA) in 1993. She is only one of 15 veterinarians in the US to hold advanced veterinary acupuncture certification. Her practice covers all of the US and exclusively involves the use of integrative therapies in chronic disease and sports medicine (equine/canine). Dr. Henneman has worked closely with SAR, police, and competitive dogs and their handlers for over 15 years and she organized the security animal sports medicine center at the 2002 Winter Olympics, incorporating thermal imaging and integrative therapies. As well as speaking at numerous conferences and writing for magazines and textbooks, she continues to be a trail veterinarian for the Iditarod Sled Dog race. Dr. Henneman can be reached at Animal Health Options in Park City, Utah or at ahooffice@aol.com.