The Importance of Foot Conformation, Foot Trimming, and Cow Comfort in the Lameness Complex

Gordon Atkins

University of Calgary, Faculty of Veterinary Medicine, Department of Production Animal Health, Calgary, AB
Email: gaatkins@ucalgary.ca

Take Home Messages

- Lameness in dairy cattle is a multifactorial condition involving foot conformation, foot trimming and cow comfort.
- Genetic improvement for foot health has been less successful than for udder conformation, mastitis control and daughter fertility.
- Confinement management on concrete has had a profound impact on foot health and the need for increased foot trimming.
- A variety of foot trimming methods are used to correct the increased foot growth and weight distribution challenges induced by traumatic, inflexible walking surfaces.
- Although the foot conformation traits of foot angle and heel depth have significant weighting in the LPI Index, they are estimated linear score values and their relationship with measured values is uncertain.
- Digital ultrasound is a useful tool to evaluate relationships with the digital cushion depth and sole depth in relation to foot conformation, body condition score and foot trimming techniques.

Lameness is an important disorder in dairy cattle, and the economic costs as a result of reduced milk production, impaired fertility, higher odds of culling, and treatment are high. Much work has been done looking at the heritability of hoof lesions, and although the heritability has been found to be low, there is considerable genetic variation as evidenced by the large variability in sire Estimated Breeding Value (EBV; Chapinal et al., 2013). In addition, the genetic correlations between hoof lesions and conformation traits have been low, showing no correlation with infectious lesions and only small correlation with horn lesions (Chapinal et al., 2013). The Lifetime Performance Index (LPI) is greatly influenced by feet and leg conformation traits and its value as a breeding tool would seem to be compromised without a more positive correlation between conformational characteristics and hoof lesions. It is reasonable to assume that the pathway for infectious hoof disease such as digital dermatitis is very different from the non-infectious disorders and the genetic component of the pathways will therefore also be different. When digital dermatitis is excluded, genetic correlation of hoof disorders increases significantly (Weber et al., 2013).

Great strides have been made in terms of genetic selection for reduced somatic cell count, improved resistance to clinical mastitis, and higher daughter fertility. But when it comes to genetic improvement for hoof health, progress has been minimal. In fact, researchers at the Canadian Dairy Network (CDN) have recently stated that “decades of selection for feet and leg type traits have not resulted in any decrease in the frequency of hoof lesions” (Van Doormaal et al., 2016). It is not clear whether other conformation evaluation parameters must be investigated, whether the emphasis on the various feet and leg traits is not appropriate, or whether we just have not accurately defined the characteristics of a functionally sound foot. In any event, CDN has adopted an alternative approach and starting in 2018 they will be developing a new genetic selection strategy for hoof health. In 2014, the four-year project called "Improving Hoof Health in Canadian Dairy Herds" began as one of several projects funded within the second Dairy Research Cluster. The project has 4 major objectives, which include:

- standardizing hoof lesion data collected by hoof trimmers across Canada
- developing a data flow process from hoof trimmers to Canadian DHI organizations and onto CDN
- developing a DHI management report for dairy producers
- developing genetic and genomic evaluations for hoof health

Standardization of hoof health data has been achieved by collecting data from hoof trimmers equipped with the “Hoof Supervisor” (KS Dairy Consulting, Inc., Dresser, WI, USA). This chute-side tablet-based program, used by hoof trimmers, specifies the type, severity, claw and zone for each lesion. An interface between Canadian DHI organizations and the Hoof Supervisor System has also been developed. This allows trimmers to download some DHI information directly into Hoof Supervisor before a herd visit, enabling herd and animal identification data to be attached to the Hoof Supervisor records. Following herd visits, trimmers routinely transfer Hoof Supervisor data (lesions, severity, actions) back to Canadian DHI organizations, which then send the data to CDN.

As we continue to expand our understanding of the factors that are necessary for cows to maintain a normal functional foot in an environment where they spend their whole lives on concrete, there surely must be anatomical characteristics that are instrumental in protecting cows from the foot lesions common to confinement management systems. Although decades of selection for feet and leg type traits have not resulted in a significant decrease in frequency of hoof lesions, many of the early decades of data collection and genetic selection were devoted to evaluating cows in tie stall barns and on farms that used pasture management. The type traits used to evaluate the foot have essentially remained the same, but the environment and the type of foot necessary to survive in that environment have changed drastically. Therefore, it is not surprising that the past selection criteria have had minimal impact on predicting the prevalence of foot lesions in today's modern cow environment. However, just as there now is a mechanism in place to upload hoof lesion data to be used in genetic evaluations, the long standing link between the classification system and CDN continues to facilitate uploading of classification information into CDN for genetic evaluations to improve longevity. The challenge we now have is to develop new techniques, perhaps new technologies, to better evaluate the anatomical characteristics of the foot and find characteristics that truly result in fewer hoof lesions. We now have the added advantage that the collection of hoof lesion data provides a new opportunity for rapid verification of the effectiveness of new anatomical data collected by classifiers.

If the identification of possible new foot anatomy selection criteria is to be complete, it should involve a discussion on foot trimming, the use of foot ultrasound, multiple cow comfort issues, and foot hygiene. With regard to foot trimming, a cow's feet no longer have the opportunity to sink into a soft pasture surface to buffer any discrepancies in weight distribution and as a result pressure points are created between the inflexible concrete surface and the foot, creating dramatically increased compensatory hoof growth and the need for much more frequent hoof trimming. The effectiveness of foot trimming therefore becomes a critical factor in maintaining healthy functional feet, and the frequency of trimming makes it more difficult to use static foot conformation evaluations as effectively as they may have been used in the past where the frequency of trimming was much less.

The trimming techniques used today vary among trimmers and it is useful to review the different trimming techniques as well as the trimming goals with regard to toe length, foot angle, heel depth, and sole thickness. There is little peer-reviewed literature evaluating different trimming techniques; however, differences seem to arise from 3 major inconsistencies in the trimming technique:

- the appropriate length to cut the dorsal wall
- the landmark of the proximal limit for measuring the dorsal wall length
- the decision to trim the toe to a point or to leave a step

It is clear that the last two points must be addressed before the first can be answered. The trimming technique most commonly used by professional trimmers, and now used for certification purposes by the Western Canadian Certified Hoof Trimmers Association, is the “Dutch Trimming” method introduced more than 30 years ago by Dr. Toussaint-Raven. Dr. Toussaint-Raven acknowledged that “normal length varies with breed and age” but in reference to toe length, he stated that “7.5 centimeters is a safe size for an adult Friesian Cow” (Toussaint-Raven, 1985). While this length seems to have become an industry standard, it is important to note that Dr. Toussaint-Raven did not define a specific landmark for the proximal dorsal wall limit and did not specify whether the 7.5 centimeter length applied to a toe that was trimmed to a point or left as a step. With the “Dutch Trimming” method currently being taught and being used in the certification process, the toe is left as a step rather than being trimmed to a point, allowing the abaxial wall to become continuous with the axial wall. In subsequent foot trimming literature, a genuine attempt has been made to precisely identify the proximal landmark for measuring the dorsal wall length and for identifying the trimming technique used at the toe. The step technique for trimming the toe is particularly helpful for new foot trimmers since it allows them to view the sole thickness from the distal flat end of the toe, and to fully appreciate the relationship between the toe length and the sole thickness. However, it has been recognized by Archer et al. (2015) that “different trimming techniques would require adaptation of dorsal wall length to achieve proper sole thickness”.

In order to define a specific proximal landmark for measuring toe length, Mülling and Budras (2003) reviewed the anatomy of the claw and concluded that the coronary band produces wall horn deep to the periople and that the perioplic horn borders the common integument and overlies the proximal limit of the wall horn. Therefore, the junction between the hoof horn and the common integument appears to be the most consistently definable landmark for measuring the dorsal wall length (Figure 1).

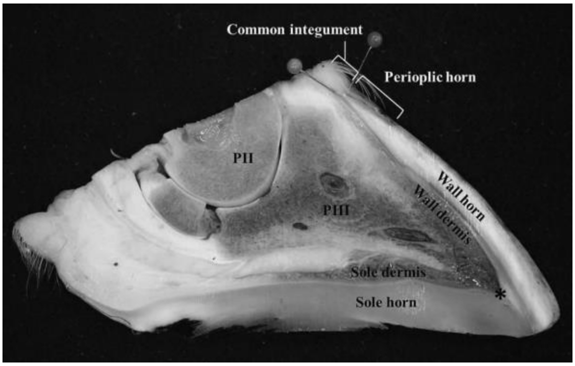


Figure 1: A green pin marks the proximal limit of the wall horn and an asterisk demonstrates the distal tip of the border between wall and dermis. A red pin identifies the proximal limit of the perioplic horn. Image reproduced from Archer et al. (2015)

Experienced foot trimmers vary claw length where the aim is to correct foot angles for optimal weight bearing. In a recent research project, experienced trimmers restored over 85% of trimmed hind feet to a foot angle between 47 and 53 degrees (Atkins, 2016). This is also consistent with the foot angle recommendations from the University of Zurich in their recommendations for proper functional claw trimming (Nuss and Braun, 2012). In order to assess the appropriateness of the 7.5 cm dorsal wall length recommendation, Archer et al. (2013) made use of computed tomography (CT) imaging on cadaver feet to correlate outer measurements with inner anatomical structures.

A cross-sectional sagittal image of the foot (Figure 2) was used to identify the distance from the proximal limit of the wall horn to the tip of the dermis at the toe. The minimum recommended external wall length was estimated by adjusting the internal wall length to accommodate a 5 mm sole thickness, a claw angle of 50°, and trimming the toe to a point as recommended in the Swiss trimming protocol (Nuss and Braun, 2012).

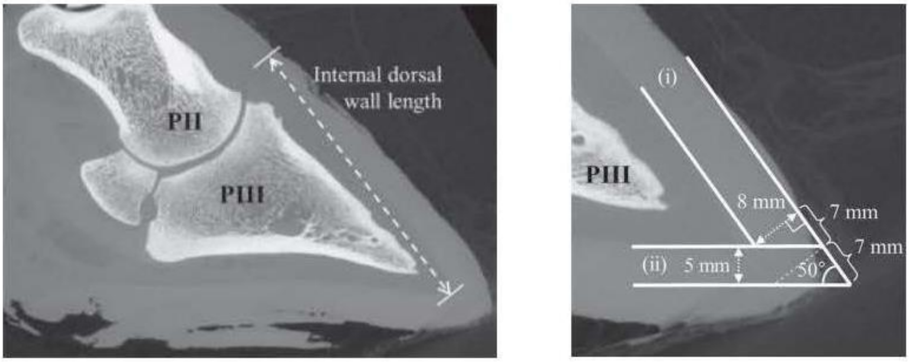


Figure 2: (a) Internal dorsal wall length is marked, being the distance from the proximal limit of the wall horn to the tip of the dermis. (b) A magnification of the toe displaying PIII, the soft tissue and both the wall and the sole horn of the claw capsule. Parallel lines extrapolate from (i) the inner and outer aspect of the wall horn, which is assumed to be 8 mm thick, and (ii) the inner margin of the sole horn at the toe and 5 mm below this margin, representing the minimum safe sole thickness. The external lines demonstrate the shape of the toe if trimmed to a point. Deduction of adjustments was based on trigonometry using a toe angle of 50°. A dashed line marks a cut perpendicular to the direction of horn growth that would leave a step at the toe for a sole thickness of 5 mm. Images reproduced from Archer et al. (2015)

To complete these calculations, it was necessary to know the thickness of the dorsal wall, which was determined to be 8 mm. It was possible by using trigonometry to calculate the minimum recommended external dorsal wall length based on these constraints and the CT measured internal dorsal wall length. Archer et al. (2015) concluded that the external dorsal wall length must be at least 14 mm greater than the internal dorsal wall length when trimming the toe to a point as seen in Figure 2. It also becomes obvious from this calculation that the external dorsal wall length must be greater when the toe is trimmed to a point, and that the toe may be 5–7 mm shorter if it is trimmed in the step configuration characteristic of the Dutch Trimming method. Therefore, where fixed toe lengths are used to simplify protocols and facilitate the training of farm staff and other less experienced operators, the minimum recommended length for trimming the dorsal wall should be conservative and identify both the proximal measuring point and the type of toe trimming. Figure 3 shows data from the author’s hoof project where toe length, foot angle, and heel depth were measured before and after trimming with the toe being trimmed to a point and the proximal measuring point being the perioplic-integument junction.

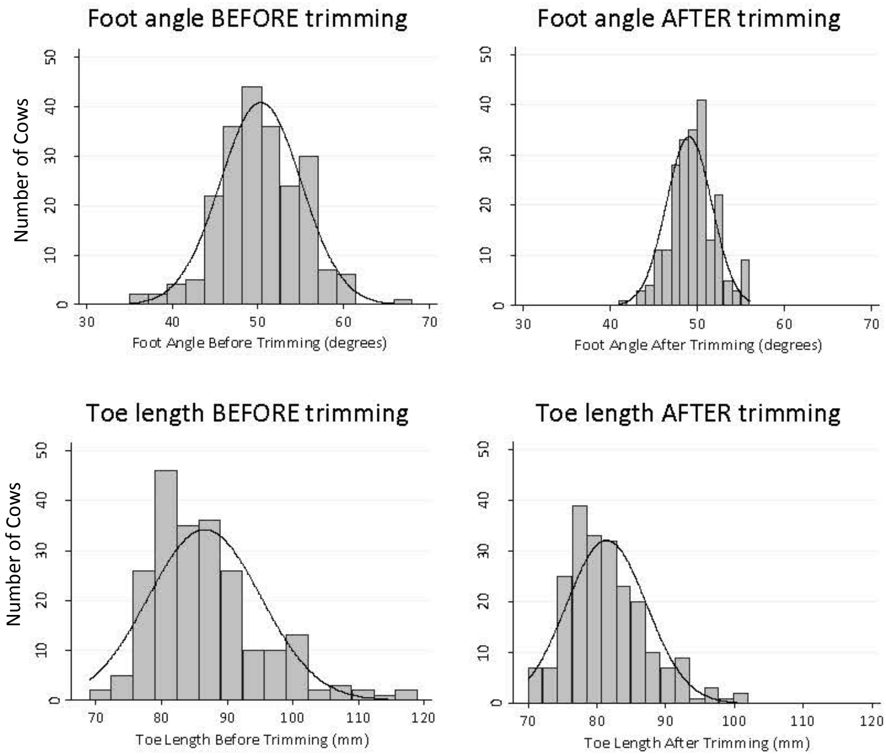
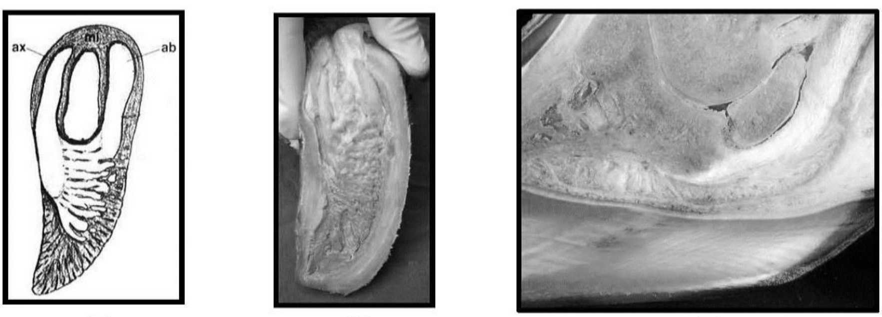


Figure 3: The range of measured foot angle and toe length before and after trimming. The mean foot angle after trimming was 50° and the mean toe length was 83 mm.

Archer et al. (2015) noted that while using this CT model and trigonometry calculation, trimming the dorsal wall length to 75 mm would have been too short for 95% of claws overall. Trimming to 85 mm would have been adequate for animals less than 4 years of age (assumed to be in first and second lactation), but too short for 34% of claws from cows aged at least 4 years. If the dorsal wall were cut to 75 mm leaving a step, 55% of claws would have been cut too short. Archer et al. (2015) acknowledge that it is unlikely that experienced trimmers will use one cut length for all cows, but will vary it, for example, by size of cow or foot. The Swiss Trimming protocol also agrees that the toe length should not be fixed and should vary with the patient (Nuss and Braun, 2012); however, where fixed lengths are to be applied at a population level, caution must be taken to minimize the proportion of claws for which that length is too short. The final difference between the Dutch and the Swiss trimming methods involves the claw that is trimmed first. The Dutch method uses the medial claw and then trims the lateral claw to match the medial claw. The Swiss method identified that the lateral claw is both longer and larger than the medial claw, and recommends that trimming should be started on the lateral claw, particularly with hind feet, so that this claw is not trimmed too short in an attempt to match it with the medial.

Recently, on a large New York dairy farm, the heritability of digital cushion thickness was found to be 0.33, while a strong negative genetic correlation was found between digital cushion thickness and claw horn lesions (Oikonomou et al., 2014). In addition, it has been previously shown that the digital cushion depth is influenced by the body condition score indicating that fat from the digital cushion is mobilized similarly to fat from other body stores. The heel depth is one of the current conformation traits that is evaluated by classifiers, but it is not known whether there is a relationship between heel depth and the digital cushion depth. Ulceration of the sole may occur in any digit but is most common in the lateral claws of the rear feet and the medial claws of the front feet. The typical site for ulceration is in the corium that overlies the flexor tuberosity of the third phalanx and it is often referred to as a "Rusterholz Ulcer". The central fat pad of the digital cushion protects this area from the trauma that results when the heel strikes the ground. With normal locomotion, the heel strikes the ground before the toe and the pedal bone at the heel is not attached to the hoof wall nearly as well by the network of collagen fibers as it is at the toe. Therefore, the cushioning property provided by the digital cushion is extremely important in preventing trauma to the corium beneath the flexor tuberosity. These anatomical relationships are illustrated in the images in Figure 4.



(a) (b) (c)

Figure 4: The images demonstrate the digital cushion components both from a solar view {(a) and (b)} and a cross sectional sagittal view (c). The solar view clearly identifies the separate axial, abaxial and central fat pads that make up the digital cushion complex. Image (a) is reproduced from Mülling and Budras (2003).

Trauma to the area beneath the flexor tuberosity creates hemorrhage at the corium, resulting in destruction of the integrity of the sole, necrosis, and the development of an ulcer as the sole grows out to the wearing surface as seen in Figure 5.

Figure 5: The image above shows a typical sole ulcer in the position beneath the flexor tuberosity of the pedal bone.

When the outer claw of the hind foot is involved, the limb is typically held in an abducted position with the cow attempting to carry more weight on the medial claw. The natural overgrowth of the lateral hind claw results in external rotation of the toe and the cow adopts a “cow-hocked” stance. In some cases, there may be a thick wedge of horn extending over the axial wall that must be trimmed to expose the lesion. As the sole horn is trimmed, a defect may be found in the sole horn that exposes the corium or a mound of granulation tissue. The loss of the sole horn in this area allows infection to involve the deeper structures of the foot, most notably, the navicular bursa, the distal inter-phalangeal joint, the heel bulb, and the tendon sheath of the deep digital flexor tendon. The environment to which the cow is exposed also has a great influence on the prevalence of sole ulcers. Poor stall and facility design leads to inadequate lying times, and if cows are confined to concrete, the constant trauma leads to a dramatic increase in trauma to the corium and consequently more sole ulcers. In order to determine the relationship between the outer heel depth and the inner digital cushion depth the author began a project first to verify the accuracy of ultrasound measurement of the digital cushion both at the flexor tuberosity and the navicular, and then to compare the ultrasound measurements with the measured heel depth in 220 Holstein cows.

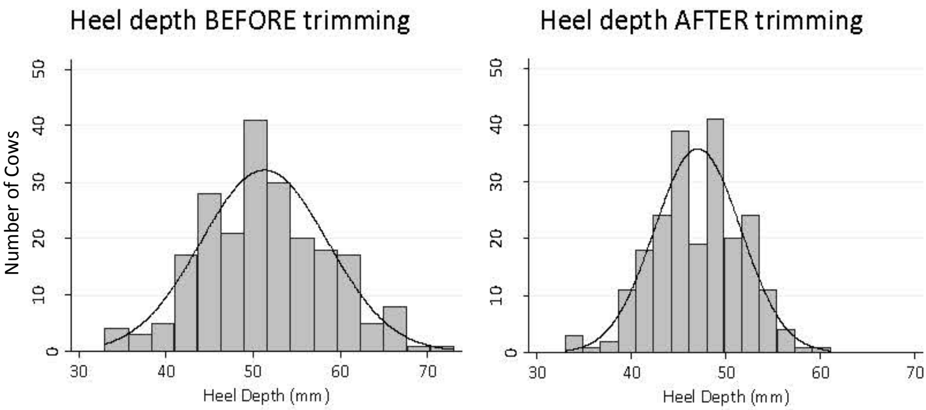


Figure 6: Range of measured heel depth before and after trimming. Mean heel depth after trimming was 48 mm.

The heel depth was measured with digital calipers both before and after trimming (Figure 6) and was identified as the perpendicular distance from the junction of the perioplic horn and the integument to the wearing surface. The digital cushion was measured with an Ibex EVO® ultrasound machine using a 5 MHz rectal probe and a gel standoff. The heel depth before trimming ranged from 33 mm to 73 mm while the digital cushion depth ranged from 15.1 mm to 32.8 mm at the navicular and 2.0 mm to 16.5 mm at the flexor tuberosity. Initial analysis indicates a very weak correlation between the external heel depth and the digital cushion depth.

In addition, the author evaluated the digital cushion depth at both the navicular and the flexor tuberosity in relation to the body condition score (BCS). This data set, although very small and not statistically significant, did show a trend toward a relationship between BCS and flexor tuberosity digital cushion thickness as previously reported at Cornell (Bicalho et al., 2009); however, no relationship was recognized between BCS and the depth of the digital cushion at the navicular. This relationship is shown in Figure 7. Very few cows were below 2.5 BCS and it may require a condition score below this point before a significant amount of fat is mobilized from the digital cushion.

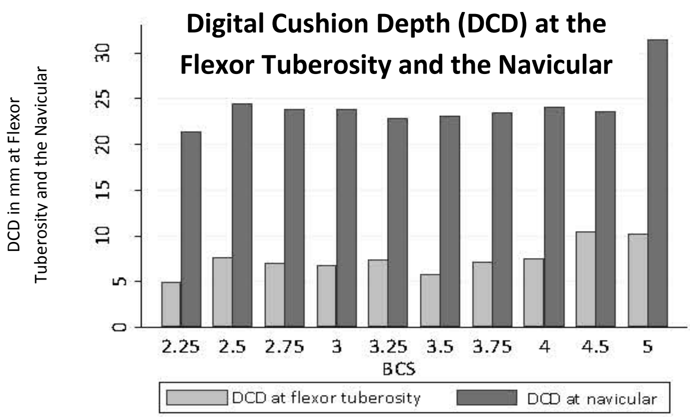


Figure 7: The relationship between BCS and the digital cushion depth (DCD) at both the flexor tuberosity and the navicular bone.

In Figure 8, the image on the left shows the point at which the digital cushion is measured beneath the flexor tuberosity and, the image on the right shows the ultrasound image of the same anatomical location facilitating the measurement of the depth of digital cushion and sole in this area.

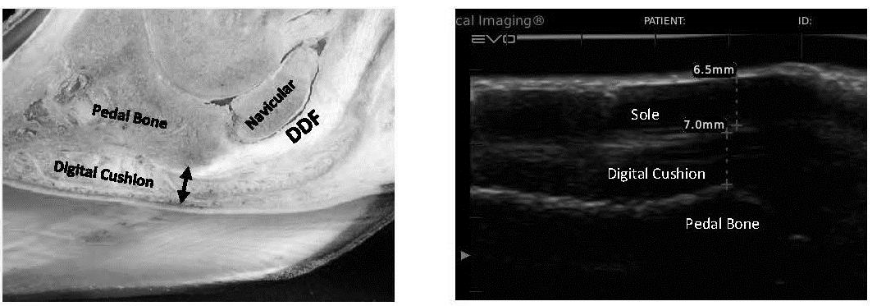
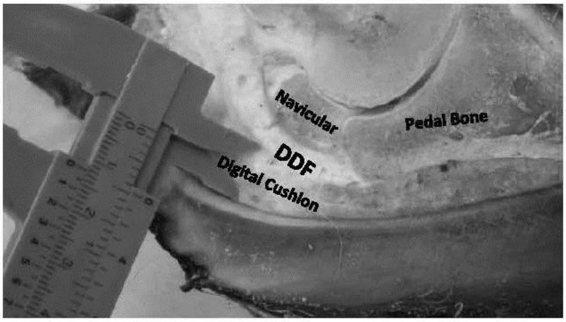


Figure 8: The image on the left shows the area where the digital cushion is measured beneath the flexor tuberosity of the pedal bone and the image on the right shows the ultrasound image and measurements generated with the probe positioned parallel to the claw and beneath the area where a sole ulcer was previously demonstrated.

The images in Figure 9 represent the anatomical location that was used to measure the digital cushion at the level of the navicular bone and the ultrasound image that facilitated the measurement of the digital cushion at this point.



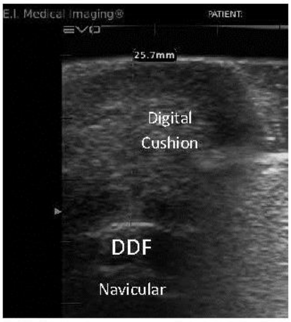


Figure 9: The image on the left shows the area where the digital cushion is measured at the level of the navicular bone and the image on the right shows the ultrasound measurement of the digital cushion with the deep flexor tendon (DDF) and the navicular bone being used as reference points.

The other anatomical parameter that was investigated in the author's research project was the measured foot angle (angle formed by the dorsal wall and the wearing surface) in relation to the estimated hairline slope that is converted to a 1–9 linear score and used by classifiers to evaluate foot angle. In performance horses this has proven to be a very important factor, and farriers use various measuring devices to ensure that the foot is trimmed to a precise angle. Such has not been the case with bovine foot trimming and the largest volume of data on bovine foot angle comes from the Canadian Classification Program where 250,000 animals are evaluated each year and their foot angle is estimated using a line extrapolated from the angle of the hairline at the coronary band and recorded as a 1–9 linear score depending on where the extended line intersects the front leg. Both the hairline and the foot angle have been used to evaluate foot angles in the horse but it must be noted that these are different measures and while a hairline angle of 30° and a foot angle of 50° have been reported as being desirable, the conformation of the leg, the heel depth, and the length of the foot from heel to toe will all influence the relationship between these two measurements.

The relationship between the hairline angle, as estimated by classifiers, and the actual toe angle measured with a protractor device in the bovine is unknown Although the process has never been validated, the classification system has assigned a linear score of 7 as the ideal for a hairline angle measurement for the hind foot, and in this case the extended line intersects the front leg at the level of the carpus. In an attempt to identify the relationship between the measured toe angle and the hairline linear score, the author measured the toe angle with a modified equine "Finnegan Gauge" using the same lateral claw of the right hind foot as Holstein Canada uses as the reference foot for classification. Pre and post trimming foot angle measurements were taken and these measurements were compared with recent hairline angle linear score classification data. An image of the modified “Finnegan Gauge” is illustrated in Figure 10.

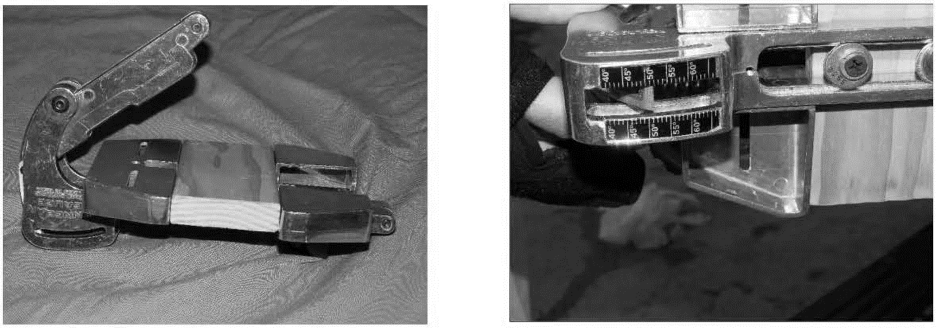


Figure 10a: Two views of the modified “Finnegan Gauge” for measuring foot angle in the bovine.

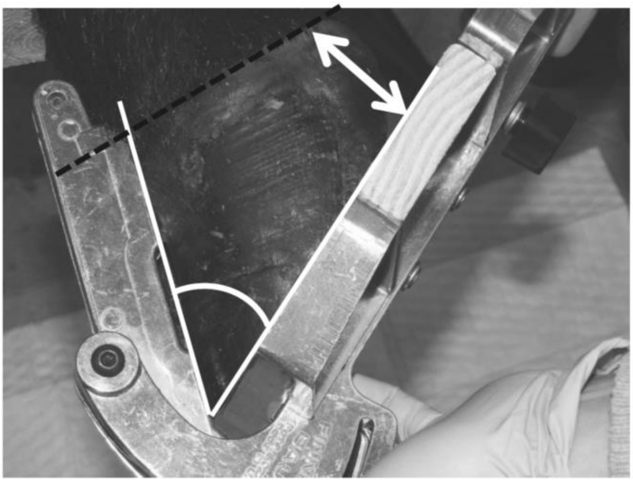


Figure 10b: The foot angle being measured on a bovine foot as well as the landmarks for measuring the hairline angle and the heel depth.

From the 220 cows that were evaluated in this project, 77 had recent classification information. The foot angle measured before trimming was used for comparison with linear scores for those cows classified just before trimming, and the foot angle measured after trimming was used for comparison with cows classified just after trimming. The relationship between measured foot angle and heel depth with the classifier estimated linear scores for those traits are shown in Figure 11.

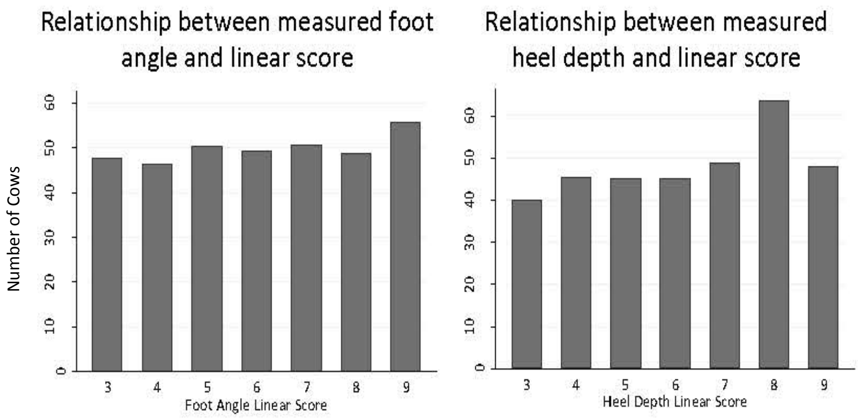


Figure 11: The image on the left represents the relationship between the measured foot angle in degrees on the y-axis and the estimated 1–9 linear score for hairline angle on the x axis. The image on the right represents the relationship between the measured heel depth in mm on the y-axis and the estimated 1–9 linear score for heel depth on the x axis. The relationships between the measured and estimated traits are very weak and require further study with much larger numbers before definitive conclusions can be made.

Acknowledgements

- WestGen Endowment Fund – financial support to conduct the project
- Dr. Laura Solano – data interpretation and statistical calculations
- Dr. Steve Mason – data interpretation
- Mr. Elbert Koster – foot trimmer
- Mr. Rob Guyer – foot trimmer
- Ms. Casey Jacobs – data recording and ultrasound measurements
- Mr. Jase Skelton – data recording and ultrasound measurements
- Dr. Kerry Atkins – data recording and ultrasound measurements
- Ms. Charlotte Pickel – data recording
- Ms. Danielle Lee – data recording
- Ms. Jasmine Voegeli – data recording

■ References

Archer, S. C., R. Newsome, H. Dibble, C. J. Sturrock, M. G. G. Chagunda, C. S. Mason, and J. N. Huxley. 2015. Claw length recommendations for dairy cow foot trimming. Vet. Rec. 177:222.

Atkins, G. 2016. Bovine lameness clinical skills manual. University of Calgary, Calgary, AB, Canada.

Atkins, G. 2016. The importance of foot conformation, foot trimming, and cow comfort in the lameness complex. Unpublished, University of Calgary Sabbatical Research Project.

Bicalho, R. C. and G. Oikonomou. 2013. Control and prevention of lameness associated with claw lesions in dairy cows. Livest. Sci. 156:96–105.

Bicalho, R. C., V. Machado, and L. Caixeta. 2009. Lameness in dairy cattle: A debilitating disease of a disease of debilitated cattle? A cross-sectional study of lameness prevalence and thickness of the digital cushion. J. Dairy Sci. 92:3175-3184.

Chapinal, N., A. Koeck, A. Sewalem, D. Kelton, S. Mason, G. Cramer, and F. Miglor. 2013. Genetic parameters for hoof lesions and their relationship with feet and leg traits in Canadian Holstein cows. J. Dairy Sci. 96:2596-604.

Mülling, C. K. W. and K .D. Budras. 2003. Pelvic limb. In *Bovine Anatomy*. Ed K. D. Budras. Schlütersche Verlagsgesellschaft, Hannover, Germany.

Nuss, K. and U. Braun. 2012. An educational film on functional foot care and trimming in cattle. Vetsuisse Faculty University of Zurich, https://cast.switch.ch/vod/clips/u4rc94l8p/link_box

Oikonomou, G., G. Banos, V. Machado, L. Caixeta, and R. Bicalho. 2014. Genetic characterization of digital cushion thickness. J. Dairy Sci. 97:532-536.

Toussaint-Raven, E. 1985. Cattle footcare and claw trimming. UK: Farming Press Ltd.

Van Doormaal. B. and L. Beavers. 2016. A step towards genetic improvement for hoof health. Canadian Dairy Network Research Article Oct 24, 2016.

Weber, A., E. Stamer, W. Junge, and G. Thaller. 2013. Genetic parameters for lameness and claw and leg disease in dairy cows. J. Dairy Sci. 96:3310-3318.