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A prospective cohort study of digital cushion and corium thickness. Part 2: Does thinning of the digital cushion and corium lead to lameness and claw horn disruption lesions?

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ABSTRACT

The aim of this study was to determine whether a decrease in thickness of the sole soft tissues (SST) beneath the flexor tuberosity of the distal phalanx (i.e., the digital cushion and corium) predisposed a claw to develop claw horn disruption lesions (CHDL) or a leg to lameness. Data were analyzed from a longitudinal study of 179 cows, which had been examined at 5 assessment points −8, +1, +9, +17, and +29 wk relative to their first, second, third, or fourth calving. At each assessment point, SST were measured using ultrasonography. Additional assessment point data included sole lesions and back fat thickness (BFT), and cows had been locomotion scored every 2 wk from calving. One hundred fifty-eight cows completed the study. Separate logistic regression survival analyses were constructed to assess the outcomes, either lameness on a leg or CHDL on a claw; combinations of lameness and lesions were tested as outcomes. Cow level variables tested included farm and lactation number. Variables were tested describing previous SST thickness, minimum previous SST thickness, BFT, and change in either variable between prior assessment points. Prior lesions/lameness strongly predicted repeat cases and the final models had the outcome first lesion or lameness on a claw or leg. In the reported lameness models, lameness was defined as a leg being recorded as lame twice within 3 consecutive scores, and in the reported lesion models, lesion was defined as the first presence of either a sole ulcer or a severe sole hemorrhage on a claw. Thin SST increased the likelihood of lesion occurrence; thin SST on the lateral claw predicted subsequent lameness on a leg. Thin BFT and thinning of BFT between previous assessment points increased the likelihood of future lesion occurrence. Thin SST and thinning of BFT had additional effects on the likelihood of lesion occurrence, suggesting that BFT and sole SST had independent effects on lesion occurrence. However, change in SST thickness between assessment points did not influence the likelihood of future lesions or lameness. This suggests that thin SST were not simply a result of depletion of body fat and challenges the theory that thinning of the digital cushion with body fat mobilization leads to CHDL. Other possible mechanisms by which SST become thin are discussed and could include changes in integrity of the suspensory apparatus with physiological events.
Key words: dairy cow, lameness, claw horn disruption lesion, digital cushion

INTRODUCTION

Lameness from claw horn disruption lesions (**CHDL**) continues to be a profound economic and a severe welfare issue in developed dairy systems (Barker et al., 2007; Cha et al., 2010; Foditsch et al., 2016). The disease process behind CHDL is not fully understood, but lesions are thought to occur in the claw capsule as a result of excessive forces on the germinal epithelium that produces the horn, causing contusions, hemorrhage, interruption to cell proliferation, epidermal differentiation and cornification, and in severe cases, complete failure of horn production, which manifests as ulceration (van Amstel and Shearer, 2006; Nuss, 2014). The forces on the germinal epithelium are exerted by the distal phalanx during foot strike and standing; therefore, the suspensory and supportive structures that determine the position of the distal phalanx within the hoof capsule appear to be pertinent in claw horn disruption.

A syndrome often termed subclinical laminitis has long been suggested to weaken the suspensory appa-

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ratus, occurring through endotoxin release secondary to SARA and a systemic inflammatory response, causing the distal phalanx to sit lower in the hoof capsule, allowing greater forces to be transferred through the sole of the foot, and predisposing CHDL. This causality has yet to be proven in relation to CHDL, and laxity of the suspensory apparatus appears to largely be superseded by mechanisms other than this classical laminitis theory (Danscher et al., 2010). For example, physiological changes around calving appear to influence the integrity of the suspensory apparatus and predispose CHDL, likely being mediated through matrix metalloproteinase activation with hormonal changes around calving (Tarlton et al., 2002; Knott et al., 2007; Newsome et al., 2017). This suggests that integrity of the suspensory apparatus in the development of CHDL appears to be important, yet not fully understood.

In addition to the suspensory apparatus, the supportive apparatus also determines the position of the distal phalanx within the hoof capsule. A key supportive structure is the digital cushion, which is a connective tissue capsule containing discrete depots of fat that sit beneath the distal phalanx (Räber et al., 2004). Several studies have measured the combined thickness of the digital cushion and corium, collectively to be termed sole soft tissues. (Importantly, previous studies assessing the digital cushion in live cows have all measured the combined thickness of the 2 tissues, rather than measuring the digital cushion alone.) Such works have demonstrated that thin sole soft tissues increased the likelihood of a cow developing CHDL, either during the lactation (Bicalho et al., 2009; Toholj et al., 2014), or during the subsequent lactation if measured at the point of the previous drying off (Machado et al., 2011). Additionally, Newsome et al. (2017) found that cows that developed sole ulcer or severe sole hemorrhage had thinner sole soft tissues, except when a sole ulcer was present on a claw, when the sole soft tissues were thicker.

Loss of body condition has been shown to precede the onset of lameness, measured by both visual detection (Lim et al., 2015; Randall et al., 2015) and lesion treatment (Green et al., 2014). A key hypothesis surrounding this association is that fat is lost from the digital cushion during negative energy balance, causing the digital cushion to become thinner, leading to a decrease in its force-dissipating capacity (Bicalho et al., 2009; Newsome et al., 2017). Although minimum thickness at a single assessment point (**AP**) has been shown to predispose lameness or lesion incidence (Bicalho et al., 2009; Machado et al., 2011; Toholj et al., 2014), no work has demonstrated that thinning of the sole soft tissues predisposes to lesions or lameness. The aims of this work were to determine whether change in sole soft tissue thickness, minimum previous sole soft tissue thickness, or sole soft tissue thickness at the previous AP predisposed CHDL or lameness in free-stall housed dairy cows.

MATERIALS AND METHODS

Study Design

A prospective cohort study, which was described in full by Newsome et al. (2017), repeatedly measured the combined thickness of the digital cushion and corium (termed sole soft tissue thickness) at 3 sites on the hind claws of dairy cows. The principal components of the study design are described here, and the null hypothesis for this analysis stated that change in sole soft tissue thickness did not increase the likelihood of either impaired locomotion or CHDL incidents.

One hundred seventy-nine Holsteins cows in 2 high-producing automatic milking system farms were studied during first, second, third, or fourth lactation, from before calving. Cows were housed year-round and farm systems are described by Newsome et al. (2017). Measurements were taken from cows at 5 AP, which were between approximately 8 wk before and 35 wk after calving (AP−8, AP+1, AP+9, AP+17, and AP+29, indicating the number of weeks relative to calving). At each of the 5 AP, cow data were collected as follows: (1) BCS on a 1 to 5 scale with quarter-point intervals (Wildman et al., 1982; Edmonson et al., 1989); (2) an ultrasonographic measurement of back fat thickness; (3) hind feet were lifted in turn, trimmed if overgrown, the sole surface was prepared for visualization of lesions, and a digital photograph of the base of the foot was taken and stored for lesion analysis; and (4) ultrasonographic measurements of sole soft tissue thickness were taken at 3 sites beneath the distal phalanx. The measurements were taken from the inner margin of the sole horn to the border of the distal phalanx, through and perpendicular to the sole, beneath (1) the apex of the distal phalanx, (2) the highest point of the arch on the base of the distal phalanx, and (3) beneath the flexor tuberosity (Newsome et al., 2017). In addition to the collection of data at AP, all cows were locomotion scored every 2 wk.

Locomotion Assessment

Locomotion scoring was performed every 2 wk between calving and 35 wk postcalving, by one trained, blinded observer on each farm. The Agriculture and Horticulture Development Board Dairy 0 to 3 mobility