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Linking bone development on the caudal aspect of the distal phalanx with lameness during life

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ABSTRACT

Claw horn disruption lesions (CHDL; sole hemorrhage, sole ulcer, and white line disease) cause a large proportion of lameness in dairy cattle, yet their etiopathogenesis remains poorly understood. Untreated CHDL may be associated with damage to the internal anatomy of the foot, including to the caudal aspect of the distal phalanx upon which bone developments have been reported with age and with sole ulcers at slaughter. The primary aim of this study was to assess whether bone development was associated with poor locomotion and occurrence of CHDL during a cow's life. A retrospective cohort study imaged 282 hind claws from 72 Holstein-Friesian dairy cows culled from a research herd using X-ray micro–computed tomography (μ-CT; resolution: 0.11 mm). Four measures of bone development were taken from the caudal aspect of each distal phalanx, in caudal, ventral, and dorsal directions, and combined within each claw. Cow-level variables were constructed to quantify the average bone development on all hind feet (BD-Ave) and bone development on the most severely affected claw (BD-Max). Weekly locomotion scores (1–5 scale) were available from first calving. The variables BD-Ave and BD-Max were used as outcomes in linear regression models; the explanatory variables included locomotion score during life, age, binary variables denoting lifetime occurrence of CHDL and of infectious causes of lameness, and other cow variables. Both BD-Max and BD-Ave increased with age, CHDL occurrence, and an increasing proportion of locomotion scores at which a cow was lame (score 4 or 5). The models estimated that BD-Max would be 9.8 mm (SE 3.9) greater in cows that had been lame at >50% of scores within the 12 mo before slaughter (compared with cows that had been assigned no lame scores during the same period), or 7.0 mm (SE 2.2) greater if the cow had been treated for a CHDL during life (compared with cows that had not). Additionally, histology demonstrated that new bone development was osteoma, also termed "exostosis." Age explained much of the variation in bone development. The association between bone development and locomotion score during life is a novel finding, and bone development appears specific to CHDL. Bone development on the most severely affected foot was the best explained outcome and would seem most likely to influence locomotion score. To stop irreparable anatomical damage within the foot, early identification of CHDL and effective treatment could be critical.

Key words: dairy cow, lameness, claw horn disruption lesion, distal phalanx

INTRODUCTION

Claw horn disruption lesions (**CHDL**) constitute a noninfectious subset of lameness-causing diseases and include sole ulcers, sole hemorrhage, and white line disease (Offer et al., 2003; Bicalho and Oikonomou, 2013). These lesions have a high rate of reoccurrence (Enevoldsen et al., 1991; Green et al., 2014; Foditsch et al., 2016), delayed detection of lameness increases the risk of more severe lameness (Bell et al., 2009), and the risk of CHDL increases as a cow ages (Sanders et al., 2009). Given that CHDL are associated with production losses, reproductive inefficiency, and poor welfare (Sprecher et al., 1997; Dyer et al., 2007; Algers et al., 2009), preventing the disease would be ideal (Potterton et al., 2012). However, their etiopathogenesis remains poorly understood; better understanding of the disease process may inform targeted prevention strategies (Algers et al., 2009; Potterton et al., 2012).

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Within the hoof capsule, the distal phalanx is suspended from the wall by laminar attachments and supported above the sole by the digital cushion (Lischer et al., 2002). The "typical" sole ulcer (one of the most severe manifestations of claw horn disruption) develops beneath the axial aspect of the flexor tuberosity of the distal phalanx (Rusterholz, 1920); sole hemorrhage is considered a precursor (Whay et al., 1997). Short ligaments attach the abaxial aspect of the distal phalanx to the abaxial hoof wall, whereas longer interdigital ligaments supporting the axial side of the distal phalanx allow greater depression of the axial aspect of the flexor tuberosity during foot-strike, perhaps leading to greater compression of the germinal epithelium at the sole ulcer site (Lischer et al., 2002). The digital cushion dissipates concussive forces transferred through the caudal aspect of the distal phalanx during foot-strike and loading, and it is thought to aid CHDL prevention by reducing peak forces on the germinal epithelium of the sole (Räber et al., 2004; Bicalho et al., 2009; Gard et al., 2015).

Bone developments appear on and around the flexor tuberosity with age (Tsuka et al., 2012) and have been termed "exostosis" (Maclean, 1970; Blowey et al., 2000; Lischer et al., 2002), indicating growth of new bone from the surface of a bone, or "enthesopathy" (Tsuka et al., 2012), indicating the inclusion of an enthesis (the insertion of a tendon or ligament onto bone). The new bone development may be an exacerbating factor for ulceration (Rusterholz, 1920; Maclean, 1970; Tsuka et al., 2012), and appears greater in cows with sole ulcers at slaughter (Tsuka et al., 2012), yet a link between lifetime history of lameness and lesions has not yet been demonstrated.

Our primary aim was to discern whether bone developments on the caudal aspect of the distal phalanx were associated with lameness from CHDL throughout a cow's life, and secondarily to define their structural composition.

MATERIALS AND METHODS

Study Design and Hypothesis

A retrospective cohort study investigated whether lameness and other variables recorded during life were associated with bone development on the caudal aspect of the distal phalanx at slaughter. The null hypothesis was that a lifetime history of poor locomotion or occurrence of CHDL (assessed using locomotion score or treatment data, respectively) was not associated with greater bone development on and around the caudal aspects of the distal phalanx at slaughter.

Study Herd

The study population consisted of cows culled from the Crichton Royal Herd at the SRUC Dairy Research and Innovation Centre (Dumfries, UK) between November 2013 and August 2014. The center comprised 2 units, Langhill and Acrehead, where cows were milked 3 times daily.

As heifers, all animals calved into the Langhill herd. The Langhill herd runs a long-term, 2 × 2 factorial design trial, genetic line × management system. Cows were between 75 and 99% pure Holstein and split into 2 genetic lines: Control and Select. Control line sires had PTA for fat plus protein yield representative of the UK average at time of breeding, whereas Select line sires had the highest available within the UK (Pryce et al., 1999). Management systems were (1) homegrown: cows were managed less intensively with access to pasture where possible (typically between April and October) and fed a high-forage diet of entirely farm-grown produce, and (2) by-product: cows were housed year round and fed a low-forage diet consisting of straw and bought-in distillery by-products, molasses, and soy (Pryce et al., 1999; Chagunda et al., 2009). Cows at Langhill were locomotion scored weekly by trained, experienced assessors following standard protocols, on a 5-point scale based on Manson and Leaver (1988). Cows given a score of 4 or 5 (defined as "obvious lameness on any leg, where behavior is affected") on a single visit or a score of 3 ("slight lameness detectable") in 2 consecutive weeks were considered lame and received veterinary treatment, as described by Randall et al. (2015). A professional foot trimmer attended both herds twice a year to trim feet deemed to be overgrown.

Acrehead is primarily a commercial unit, and locomotion score data were not routinely captured. Cows were moved from Langhill to Acrehead at the end of their fourth lactation, although they could have been moved earlier due to incidence of mastitis, poor fertility, or requirements of experimental protocols in the Langhill herd. Therefore, locomotion data immediately preceding slaughter were only available for cows that had recently been at Langhill. Culling occurred in both herds based on commercial or health and welfare grounds.

Sample Collection

The hind feet of all cows culled from either herd between the specified dates were collected postmortem at an abattoir, uniquely identified, and transported on ice to the University of Nottingham for storage at −20°C.