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Original Article

Effect of claw horn lesion type and severity at the time of treatment on outcome of lameness in dairy cows

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Highlights

- Recovery from lameness in dairy cattle after treatment was studied in relation to type and severity of claw horn lesion.
- At weeks after therapeutic hoof trimming, 78.6% of cows had recovered from lameness.
- Severity of claw horn lesion was negatively related to the size of the lesion.
- The presence of white line lesions was associated with a reduced likelihood of recovery from lameness.
- Severely lame cows were less likely to recover than those that were mildly lame.

Abstract

Prompt diagnosis and treatment of claw horn lesions in cattle affects the likelihood of recovery; however, it is unknown if the type of lesion influences the likelihood of recovery. The aim of this study was to investigate whether the type, severity and frequency of claw horn lesions in newly lame cows (lame for no more than 2 weeks) at the time of corrective foot trimming affects the probability of recovery from lameness after treatment. The images of 112 feet (224 claws) from newly lame cows (n = 112; lame in only one hind foot), which were treated with a standardised therapeutic hoof trim only, were used to score claw horn lesions (sole ulcer, sole haemorrhage, white line haemorrhage or white line separation). Most cows (n = 107/112; 95.5%) were classified as mildly lame at the time of treatment. The proportion of cows that recovered 2 weeks after therapeutic hoof trimming was 88/112 (78.6%). Results of a multilevel logistic regression model indicated that severely lame cows were less likely to recover than those that were mildly lame (odds ratio, OR, 0.16; P = 0.04). White line haemorrhage had a significant negative impact on the likelihood of recovery from lameness (OR 0.14; P > 0.01); however, recovery of cows with white line haemorrhage was positively associated with the length of the lesion (OR 1.05; P = 0.03). This latter finding may be associated with the severity of the lesion, since mild claw horn lesions affected a significantly larger area of the claw than more severe lesions. The length and type of claw horn lesion was associated with recovery from lameness.

Keywords: Dairy cows; Lameness; Claw horn lesions; White line haemorrhage; Foot trimming

Introduction

The most common causes of lameness in dairy cows in the United Kingdom (UK) are lesions that cause disruption of the claw horn, including sole ulcer (SU), sole haemorrhage (SH) and white line disease (WLD), the latter divided into white line haemorrhage (WLH) and white line separation (WLS) (Leach et al., 2012; Green et al., 2014). SU and WLD can cause milk losses of approximately 570 and 370 kg, respectively, over a full lactation (equating to a loss of £91 and £59, respectively, for each lesion)[1] (Amory et al., 2008). SU and SH are positively associated with early culling (Booth et al., 2004; Sogstad et al., 2007a). Furthermore, claw horn lesions are painful and can be associated with hyperalgesia; Whay et al. (1998) reported that this continued for up to 28 days from the time of assessment of lameness. SU is considered to be the most severe of the lesions that cause disruption of the claw horn and has been associated with poor locomotion, asymmetric steps, increased back arch and reduced joint flexion, all indicating a pain response (Flower and Weary, 2006; Chapinal et al., 2009; Tadich et al., 2010).

Early diagnosis and treatment may improve prognosis and recovery rates in lame cows (Leach et al., 2012). These authors reported that earlier lameness interventions were more likely to be carried out on less severe lesions, improving the likelihood of recovery. Early treatment of cows with mild lameness, within 2 days of detection, was associated with a reduction in the herd prevalence of lameness when compared with study protocols (treatments carried out by farmers following their own procedures) which led to a delayed time to treatment. In this early intervention study, milder lesions (i.e. haemorrhage) were observed in early treated cows, with more ulcers present when treatment was delayed. The aim of the present study was to examine whether the type, severity and size of claw horn lesions in newly lame cows identified at the time of corrective foot trimming influenced the probability of recovery from lameness after treatment.

Materials and methods

Experimental design

The present study used data collected during a randomised clinical trial (RCT) described by Thomas et al. (2015). The RCT protocol was reviewed and approved by the University of Nottingham School of Veterinary Medicine and Science Ethical Review Committee (protocol number 453 111022; date of approval 31 October 2011). The RCT was designed to compare three treatments for claw horn lesions against a positive control group that received a therapeutic trim only. Cows on five farms were scored for mobility every 2 weeks following the UK industry standard scoring scheme[2], and were eligible for examination and treatment if they had two non-lame scores followed by a lame score, and only presented with lameness in one of the hind limbs.

[1] Margin over all feeds used to estimate financial loss; a value of £0.16/L was used based on an average farm gate milk price of £0.28/L. Conversion rate of UK£1 = US$1.61 = €1.23 as at December 2012.

[1] See: AHDB Dairy: Mobility Score - Instructions Laminate. https://dairy.ahdb.org.uk/resources-library/technical-information/health-welfare/mobility-score-instructions/#.WL-MxxAu6wA (accessed 9 May 2012).

Photographs and mobility scores of cows with claw horn lesions that only received a therapeutic foot trim on the detected lame hind limb were included; the intervention was a standard Dutch five step trim, involving trimming and balancing of both claws, investigation of lesions and removal of diseased horn (Toussaint-Raven et al., 1985). The study group included cows with a single claw affected (37 animals) or both claws affected (106 animals). Study cows that recovered from lameness and those that were still lame on the same limb at the 2 week outcome point were kept in the data set; cows that became lame on a different limb after treatment were excluded. Recovery from lameness was defined as a cow that was non-lame at the mobility score assessment 2 weeks after treatment.

Lesion identification and scoring

A photograph was taken of the plantar surface of the hoof of the lame hind limb following completion of all trimming. If the therapeutic trim (conducted using hoof knives) had not required horn to be removed from any areas of the sole, a thin layer of stained superficial claw horn was removed to allow visualisation of any lesions present over the whole plantar surface. The surface of the claw was cleaned with water and dried with paper towels. Photographs were taken using a Sony Cybershot camera (DSC-W170 10.1 megapixels). A small identification board (101 mm x 228 mm; with cow identification number and date noted) was held next to the hoof to mark each image. To identify claws (medial or lateral), the board was always positioned on the lateral side of the lateral claw.

Lesions present on hoof photographs were identified, classified and located according to a methodology adapted from published literature (Greenough and Vermunt, 1991; Leach et al., 1998; Sogstad et al., 2007a) (Table 1). All lesions were identified, classified and scored for severity by a single observer. The length or area of each lesion were measured using ImageJ 1.49p (Schindelin et al., 2012), which calculated length and area in pixels. The lesion size data were transformed to length of WLD lesions (in mm) and area of SH or SU lesions (in mm^2) using the width of the identification board as a reference to adjust for small variations in camera distance from the foot. Data were transferred to an Excel spreadsheet.

Zones of the sole were identified according to Greenough and Vermunt (1991) (Fig. 1a). Information was recorded on the presence or absence of heel horn erosion (i.e. irregular horn

surface with or without deep horn grooves that may expose the corium), double sole (i.e. two or more layers of underrun sole horn) and interdigital hyperplasia (Blowey, 1992)[3].
The intra-observer reliability to correctly measure the lesions was assessed through measuring the outline of a claw at the beginning and at the end of the picture session on three occasions throughout the study. The intra-observer reliability for lesion identification (type and severity; Table 1) was assessed using the same series of 25 pictures of lesions at each of four testing sessions prior to commencing, twice during and at the end of the picture observations. Images were presented in a random order at each session.

Statistical analysis

Sample size was calculated on the basis of the rate of recovery published by Groenevelt et al. (2014). Using a one-proportion score test in Stata/SE 12.0 (Stata Corp), with an expected 80% recovery after 2 weeks, with a confidence level of 95% (95% CI) and a power of 80%, the calculation estimated that a sample size of 86 cows was required.
Descriptive and reliability analyses were carried out using Stata/SE 12.0. The weighted kappa (k_w) was used to calculate the intra-observer reliability for lesion scoring and the interpretation of the k_w was conducted according to Landis and Koch (1977). Areas for each lesion severity category were not normally distributed, so the Kruskall Wallis test (H) was used to compare severity categories for each type of lesion (Petrie and Watson, 2006). A P value of ≤ 0.05 was considered to be significant.
A multilevel logistic regression model was built using MLwiN version 2.27[4]. The two level (claw clustered within cow) model examined if area or length and presence (yes or no) of claw horn lesions affected the likelihood of recovery; recovery at 2 weeks was set as a binary outcome. Fixed effects included farm, cow identification, claw affected (lateral, medial or both), mobility score before treatment, lesion type present (yes or no; Table 1), area (mm^2) or length (mm) measurement and frequency for each lesion type (area for SU and SH; length for WLH and WLS), heel horn erosion (HHE; yes or no) and double sole (yes or no). An additional variable was included to distinguish between operators at the time of treatment, categorised as either the primary operator (a trained veterinary surgeon who was the trimmer in charge during the study) or secondary operators (relief trimmers who treated cows to cover vacations). Data for severity category for each type of lesion was not included in the final model, due to low representation of each lesion type, particularly at the most severe category (Table 2). This data was consolidated to obtain a total area or length and frequency per claw horn lesion type to evaluate the main aim of the study.
Results from the model are presented as odds ratios (ORs) and 95% CIs. Non-significant variables were kept in the final model due to their importance as risk factors for recovery or due to their biological importance. Frequency and presence of claw horn lesions by type showed high collinearity; similarly, the total number of lesions per claw was highly correlated with the presence or absence of lesions; therefore, only the presence of claw horn lesions by type was kept in the final model.

Results

Prevalence and description of claw horn lesions

Data from 143 cows were available for analysis, of which seven did not have any visible lesions, 11 became lame on a different limb 2 weeks after treatment, six were diagnosed with digital

[3]See: ICAR Claw Health Atlas. International Committee for Animal Recording. http://www.icar.org/documents/icar_claw_health_atlas.pdf (accessed 9 May 2012).
[4] See: MLwiN Version 2.1. http://www.bristol.ac.uk/cmm/software/mlwin/refs.html (accessed 9 May 2012).

dermatitis and pictures from seven cows were excluded because the image quality was too poor or they were ambiguously identified. The final data set consisted of images of 224 claws from 112 cow lameness events.

The prevalence of lesions varied according to claw; three cows had SH lesions on both claws, three cows had WLD on both claws, 51 cows had both claws affected by different combinations of lesions and the remaining 55 cows had different combinations of lesions by claw (e.g. one claw with SH and the other claw with a SU). SH was the most frequently observed lesion (n = 210 lesions; Table 2), followed by WLH (n = 133) and WLS (n = 58). The least frequent claw horn lesion was SU (n = 47 lesions). Most of the lesions were located on the lateral claw, whereas 53.6% of HHE and 60% of double sole were located on the medial claw.

Effect of claw horn lesions on the recovery from lameness

The proportion of cows that recovered from lameness 2 weeks after therapeutic hoof trimming was 88/112 (78.6%; Table 3). Results from the final model showed that only WLH had a significant negative impact on the likelihood of recovery from lameness (OR 0.14; 95% CI 0.04-0.55; P = 0.004). Recovery of cows with WLH was positively associated with the length of the lesion (OR 1.05; 95% CI 1.00-1.09; P = 0.03). Cows assigned a mobility score of 3 at the time of treatment were significantly less likely to recover than cows with a mobility score of 2 (OR 0.16; 95% CI 0.03-0.90; P = 0.04). Hoof trimming operator (primary or secondary) had a significant effect on the likelihood of recovery (OR 0.12; 95% CI 0.03-0.44; P = 0.001); animals treated by the primary operator were more likely to recover. Other lesion types had no significant association with the likelihood of recovery.

Association between size of lesions and severity

The mean SU area categorised as mild was significantly greater than the area categorised as severe (H = 4.6, 1 df; P = 0.0001) (Fig. 2). The mean SH area categorised as mild was significantly greater than the areas categorised as either moderate or severe (H = 91.0, 2 df; P = 0.0001) (Fig. 2). The mean WLH and WLS lengths categorised as mild were significantly longer than the lengths categorised as moderate and severe (WLH: H = 40.2, 2 df; P = 0.0001; WLS: H = 7.6, 2 df; P = 0.0001; Fig. 2).

Reliability of area and length measurement and lesion identification

The average standard deviation of the mean of each measurement assessed was 3.0% (range 1.4-7.2%) after measuring the lesion area and length on the same claw six times. The intra-observer overall average k_w agreement for lesion classification was very high (k_w = 0.87; 95% CI 0.75-0.96); the observer was able to identify with high reliability the type and severity classification of claw horn lesions during the four testing sessions.

Discussion

This study identified associations between the types of lesion present at the time of treatment by hoof trimming in newly lame dairy cows and the likelihood of recovery in the immediate post-treatment phase. Lesions recorded were those that could be visually identified within the semi-transparent sole and white line following the completion of a therapeutic trim. Our results provide useful prognostic information based on field assessment of lesions visible following the completion of a trim. However, it was not feasible to assess the depth of these lesions, including their position relative to the corium and their extent within the thickness of the sole or white line, by visual inspection.

In newly lame dairy cattle, the presence of WLH at the time of treatment was associated with a decrease in the likelihood of recovery from lameness following a therapeutic trim after controlling for the presence of other claw horn lesions. The length of WLH was positively correlated with the likelihood of recovery, i.e. cows with longer WLH lesions were more likely to recover from lameness 2 weeks after treatment than cows with shorter WLH lesions. Mild WLH lesions were significantly longer than the other severity categories of WLH. It is difficult to compare these results with previous studies, which often have not discerned between WLH, WLS and WLU (Amory et al., 2008; Chapinal et al., 2009).

SU, SH and WLS have been associated with lameness by Manske et al. (2002b), but the presence of these lesions did not have a significant effect on the likelihood of recovery from lameness in our study. Cows in our study were treated with a therapeutic trim only, i.e. no other treatments, such as the application of foot blocks, were provided. It is possible that the treatment applied in the present study, which was aimed at trimming and balancing the claws and removing diseased horn, was able to reduce pressure and hence lameness, whereas such treatment may not have achieved these results for WLH.

In agreement with previous studies (Leach et al., 2012; Groenevelt et al., 2014), SH was the most prevalent lesion in the present study. In a study by Flower and Weary (2006), SH was not associated with poor locomotion scores. Chapinal et al. (2009) found a strong association between SU and poor locomotion scores up to 4 weeks before diagnosis. In our study SU was diagnosed in 47/224 (21.0%) claws, although most claws/feet exhibited a combination of lesions. It is difficult to make comparisons between studies, since some have combined all lesions observed in each foot, or have only considered moderate to severe lesions in their results (Chapinal et al., 2009; Tadich et al., 2010).

Cows in the present study became lame within the 2 weeks prior to treatment. These animals may have experienced trauma at the level of the corium, manifested through the presence of haemorrhages, which may predispose to more severe lesions if left untreated or allowed to progress (Sogstad et al., 2007b; Groenevelt et al., 2014). Most of the claw horn lesions were observed in the lateral claw (Table 2), consistent with previous observations (Ahrens et al., 2011). Cows with lesions on the lateral claw only were neither more or less likely to recover compared to cows with lesions on the medial claw only or to cows with lesions on both claws. This is surprising given that the lateral claw on the hindlimbs bears more weight when standing and strikes the floor first while walking (Van der Tol et al., 2002; Schmid et al., 2009).

The severity of a claw lesion was inversely proportional to size, which was true for every claw horn lesion type observed. This might reflect the way pressure forces in the corium are distributed (Van der Tol et al., 2002). However, the descriptors used in the present study were derived from previous studies, which were based on the appearance of the lesions rather than size (Leach et al., 1998; Sogstad et al., 2005). Further work is needed to investigate how the combination of area, length, depth, severity and lesion type are related to recovery from lameness.

At 2 weeks after treatment, 88/112 (78.6%) cows had recovered from lameness, similar to that observed by Groenevelt et al. (2014). Manske et al. (2002a) reported that 87% of cows had recovered from lameness 4 months after foot trimming. Prompt intervention is more likely to encounter mild lesions that are less complicated to treat, increasing the chances of a rapid recovery and less lameness in the following lactations (Groenevelt et al., 2014).

Cows in the present study were treated using the five step Dutch foot trimming technique (Toussaint-Raven et al., 1985). Lame cows treated by the primary operator were more likely to recover than those treated by secondary operators, after controlling for the presence of different claw horn lesions. The finding highlights differences between operator outcomes, even when a standardised approach is followed. Previous research has suggested that foot trimming may cause pain and discomfort (Chapinal et al., 2010; Van Hertem et al., 2014); although foot trimming in

these studies was performed by experienced operators, the hoof trimming technique was not specified.

Conclusions

Cows that were severely lame at the time of treatment, and those with white line haemorrhage, were less likely to have recovered from lameness 2 weeks after treatment than those diagnosed with WLS, SH or SU. In addition, cows with WLH of greater length were more likely to recover; this may be related to the severity of the lesion, since larger lesions tended to be less severe. Further work is needed to understand the factors that influence recovery from lameness following treatment, to maximise recovery and to limit the welfare impact of foot disease in cattle.

Conflict of interest statement

None of the authors has any financial or personal relationship that could inappropriately influence or bias the content of the paper.

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Table 1

Severity classification and description of claw horn lesions, adapted from Greenough and Vermunt (1991), Leach et al. (1998) and Sogstad et al. (2007a).

	Classification	Description
No lesion		No claw horn lesion or any other lesion identified on the foot
Sole ulcer	Mild	Disruption of sole surface, corium not exposed or granulation tissue not observed
	Severe	Penetration of sole surface with exposure of corium and/or granulation tissue present
Sole haemorrhage	Mild	Presence of diffuse light pink and/or yellow colouration at any location on the sole
	Moderate	Presence of dark pink colouration at any location on the sole
	Severe	Presence of very dark red or purple colouration at any location on the sole
White line haemorrhage	Mild	Presence of diffuse light pink and/or yellow colouration at any location on the white line
	Moderate	Presence of dark pink colouration at any location on the white line
	Severe	Presence of very dark red or purple colouration at any locations on the white line
White line separation	Mild	Dark coloured marks on the white line at any location
	Moderate	Deep fissures and/or impacted areas in the white line at any location
	Severe	Very deep fissure, with the corium involved and/or purulent exudate, necrosis, granulation tissue and/or separation of wall and sole at any location

Table 2
Frequency, severity and distribution of types of claw horn lesions by severity in 112 cows (224 claws).

	Severity	Lateral claw	Medial claw	Total for severity	Total for lesion
Sole ulcer	Mild	25 (67.6)	12 (32.4)	37 (78.7)	47
	Severe	8 (80.0)	2 (20.0)	10 (21.3)	
Sole haemorrhage	Mild	87 (68.5)	40 (31.5)	127 (60.5)	210
	Moderate	36 (63.2)	21 (36.8)	57 (27.1)	
	Severe	18 (69.2)	8 (30.8)	26 (12.4)	
White line haemorrhage	Mild	47 (54.7)	39 (45.3)	86 (64.6)	133
	Moderate	22 (64.7)	12 (35.3)	34 (25.6)	
	Severe	10 (76.9)	3 (23.1)	13 (9.8)	
White line separation	Mild	18 (47.4)	20 (52.6)	38 (65.5)	58
	Moderate	9 (52.9)	8 (47.1)	17 (29.3)	
	Severe	3 (100.0)	0	3 (5.2)	
Heel horn erosion		32 (46.4)	37 (53.6)		69
Double sole		10 (40.0)	15 (60.0)		25

Percentages of lesions by severity and by type are in parentheses.

Table 3
Multilevel logistic regression analysis of the likelihood of recovery from lameness caused by claw horn lesions 2 weeks after therapeutic trimming.

	Frequency of observations	Coefficient of variation	Standard error	Odds ratio	z	Confidence interval		*P* value
						2.5%	97.5%	
Constant [a]		0.871	0.56					
Farm								
Farm 1	44	Reference						
Farm 2	36	0.473	0.67	1.6	0.51	0.44	5.91	0.48
Farm 3	6	-0.323	1.15	0.7	0.08	0.08	6.92	0.78
Farm 4	52	0.891	0.64	2.4	1.94	0.70	8.55	0.16
Farm 5	86	0.538	0.61	1.7	0.79	0.52	5.62	0.37
Mobility score (MS) at time of treatment								
MS 2	214	Reference						
MS 3	10	-1.845	0.91	0.2	4.10	0.03	0.9	0.04
Claw affected								
Lateral	48	Reference						
Medial	8	0.26	1.16	1.3	0.05	0.13	12.7	0.82
Both	168	0.586	0.53	1.8	1.25	0.64	5.03	0.26
Operator								
Primary operator	206	Reference						
Secondary operator	18	-2.137	0.67	0.1	10.17	0.03	0.44	0.001
Ulcers								
Area (mm^2)	224	-0.006	0.004	1.0	2.25	0.99	1.00	0.13
No	180	Reference						
Yes	44	1.239	0.87	3.5	2.02	0.63	19.03	0.15
Haemorrhage								
Area (mm^2)	224	0.001	0.001	1.0	1.00	1.00	1.00	0.32
No	78	Reference						
Yes	146	0.196	0.47	1.2	0.17	0.48	3.07	0.68
White line haemorrhage								
Area (mm)	224	0.05	0.02	1.1	4.80	1.00	1.09	0.03
No	123	Reference						
Yes	101	-1.947	0.69	0.1	8.08	0.04	0.55	0.004
White line separation								
Area (mm)	224	-0.03	0.03	1.0	0.69	0.92	1.03	0.40
No	174	Reference						
Yes	50	0.7	0.90	2.0	0.61	0.35	11.71	0.44
Heel horn erosion								
No	157	Reference						
Yes	67	-0.33	0.57	0.7	0.34	0.24	2.18	0.56
Double sole								
No	200	Reference						
Yes	24	-0.118	0.71	0.9	0.03	0.22	3.55	0.87

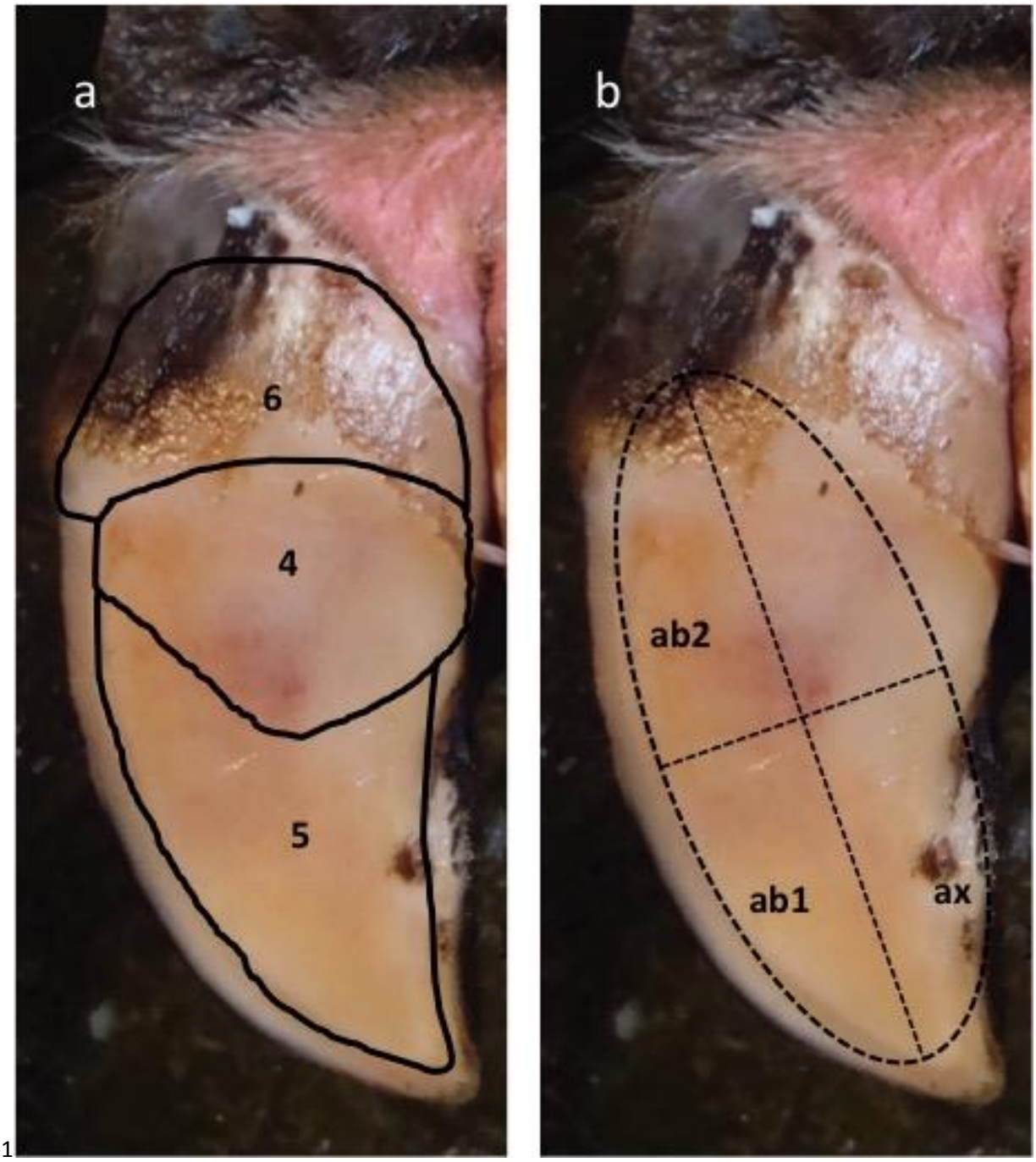
[a] Constant: Intercept, the value at which the fitted model line crosses the y-axis.

Figure legends

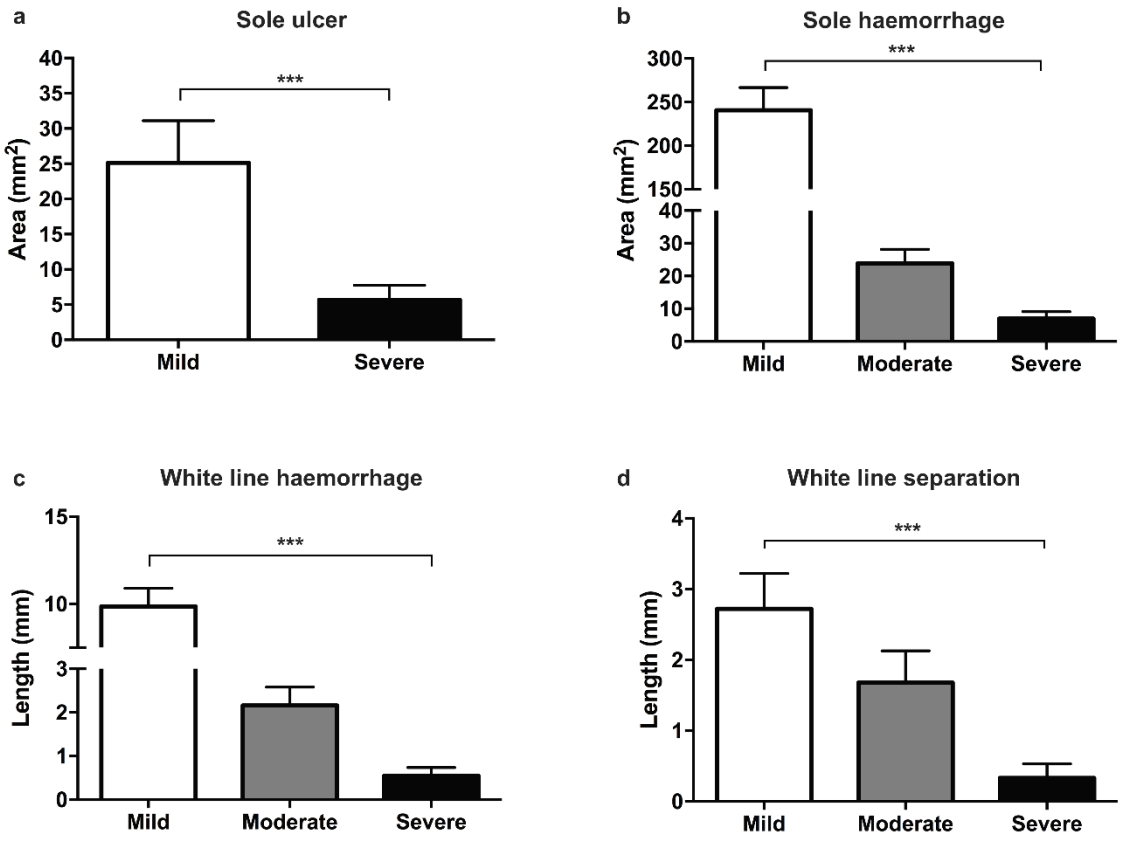
Fig. 1. Zones of the plantar surface of the claw used to describe the location of claw horn lesions, modified from Leach et al. (1998). (a) Zones for sole ulcers and haemorrhage (4, sole; 5, toe; 6, heel). (b) Zones for white line disease lesions (ab1, abaxial wall zone 1; ab2, abaxial wall zone 2; ax, axial wall.

Fig. 2. Distribution of area of sole ulcer (a) and sole haemorrhage (b), and length of white line haemorrhage (c) and white line separation (d), with standard errors, measured on pictures by severity scored on a categorical scale. *** $P < 0.001$.

Whay, H.R., Waterman, A.E., Webster, A.J.F., O'Brien, J.K., 1998. The influence of lesion type on the duration of hyperalgesia associated with hindlimb lameness in dairy cattle. The Veterinary Journal 156, 23-29.



Figr-1



Figr-2