

1 **Original Article**

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4 **Effect Of Claw Horn Lesion Type At The Time Of Treatment On Lameness**
5 **Prognosis**

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17 **ABSTRACT**

18 Claw horn lesions are some of the most common causes of lameness and it is accepted that
19 prompt diagnosis and treatment affects the likelihood of recovery; however, it is still
20 unknown if the type of lesion influences the likelihood of recovery. The aim of this study was
21 to investigate whether the type and frequency of claw horn lesions in newly lame cows at the
22 time of corrective foot trimming affected the probability of recovery from lameness after
23 treatment. The images of 119 feet from newly lame cows, which were treated with a
24 standardised therapeutic hoof trim, were used to measure and count the presence of claw horn
25 lesions (sole ulcer, sole haemorrhage, white line haemorrhage and white line separation). The
26 majority of cows (n=114) were classified as mildly lame at the time of treatment. The
27 recovery rate two weeks after therapeutic hoof trimming was 79.8% (n=95 cows). A
28 multilevel logistic regression model found that severely lame cows with lesions on a single
29 claw were less likely to recover than those that were mildly lame and had lesions on both
30 claws. White line haemorrhage lesion was the only lesion to decrease the likelihood of
31 recovery; however, cows with longer white line haemorrhage lesions were more likely to
32 recover. This latter finding may be associated with the severity of the lesion, as this study also
33 observed that mild claw horn lesions were significantly larger than severe lesions. Further
34 work is needed to better understand the factors that influence recovery from this painful and
35 costly disease.

36 **Keywords:** Lameness, dairy cows, claw horn lesions, recovery rate, lameness prognosis

37 INTRODUCTION

38 The most common causes of lameness in dairy cows in the UK are the lesions of claw horn
39 disruption, which include sole ulcers (SU), sole haemorrhage (SH) and white line disease
40 (WLD) (Green et al., 2014; Leach et al., 2012). SU and WLD can cause milk losses of
41 approximately 570 and 370 kg respectively (Amory et al., 2008). SU and SH have been
42 positively associated with a reduction in longevity and earlier culling (Booth et al., 2004;
43 Sogstad et al., 2007a). Further, claw horn lesions are painful and can propagate hyperalgesia;
44 Whay et al. (1998) reported that this continued for up to 28 days. SU is considered to be the
45 most severe of the claw horn disruption lesions and has been associated with poor
46 locomotion, asymmetric steps, increased back arch and joint flexion, all indicating a pain
47 response (Chapinal et al., 2009; Flower and Weary, 2006; Tadich et al., 2010).

48 Early diagnosis and treatment may improve prognosis and recovery rates in lame cows (Leach
49 et al., 2012). These authors reported that earlier lameness interventions were more likely to be
50 carried out on less severe lesions, improving the likelihood of recovery. Early treatment of
51 cows with mild lameness, within 2 days of detection, reduced herd lameness prevalence when
52 compared with protocols, which led to a delayed time to treatment. In this early intervention
53 study, milder lesions (i.e. haemorrhage) were observed in early treated cows, with more ulcers
54 present when treatment was delayed.

55 As previously described, claw horn lesion type has been linked to different production traits
56 and survival rates. However, the effect of claw horn lesion type at the time of treatment on the
57 likelihood of recovery has not been studied. The primary aim of this study was to examine
58 whether the type and frequency of claw horn lesions in newly lame cows identified at the time
59 of corrective foot trimming had an effect on the probability of recovery from lameness after

60 treatment. The null hypothesis stated that the type and frequency of claw horn lesion(s) did
61 not affect recovery from lameness after treatment.

62 **MATERIALS AND METHODS**

63 *Study dataset*

64 The present study used data collected during a randomised clinical trial (RCT) described by
65 Thomas et al. (2015). In brief, the RCT was designed to compare three treatments for claw
66 horn lesions against a positive control group that only received a therapeutic trim only. The
67 RCT protocol was reviewed and approved by the University of Nottingham's School of
68 Veterinary Medicine and Science Ethical Review Committee prior to the start of the study.

69 *Animals.* Data from cows selected for the present study were a subset drawn from the study
70 population described in Thomas et al. (2015). In brief, cows on 5 farms were mobility scored
71 every two weeks and were eligible for examination and treatment if they had two non-lame
72 scores followed by a lame score, and only presented with one of the hind limbs lame. Cows
73 with claw horn lesions classified into one of three categories were included in the study (SH
74 or SU, WLD or 'Other' (other types of claw horn lesion or a combination of SH, SU and / or
75 WLD); those with infectious lameness conditions were not enrolled. The treatment group had
76 been randomly assigned and the dataset used in this study included *only* cows that received a
77 therapeutic foot trim alone (Standard Dutch 5 step therapeutic foot trim involving trimming
78 and balancing of both claws, investigation of lesions and removal of diseased horn
79 (Toussaint-Raven et al., 1985)). If study cows were still lame on the same leg at the two-week
80 outcome point they were kept in the dataset, cows that became lame on a different leg after
81 treatment were excluded.

82 *Sample size.* Sample size was calculated based on the rate of recovery published by
83 Groenevelt et al. (2014). Using a one-proportion score test in Stata/SE 12.0 (Stata Corp 2011,

84 USA), with an expected 80% rate of recovery after 2 weeks with a confidence level of 95%
85 and a power of 80%, the calculation estimated a sample size of 86 cows was required.

86 *Hoof photographs*

87 At the time of treatment, pictures were taken of the plantar surface of the hoof of the lame leg,
88 after a very thin layer of claw horn had been removed. The claw's surface was cleaned with
89 water and dried with paper towels. Photographs were taken using a Sony Cybershot camera
90 (DSC-W170 10.1 megapixels, Sony Europe Limited). A small identification board (101 x 228
91 mm) was held next to the hoof to mark each image.

92 *Lesion identification and scoring*

93 Lesions present on hoof photographs were identified, classified and located according to a
94 standard methodology developed at the University of Nottingham; lesion classifications are
95 described in Table 1, adapted from published literature (Greenough and Vermunt, 1991;
96 Leach et al., 1998; Sogstad et al., 2007a). A single observer identified, classified and severity
97 scored all the lesions by claw (Table 1). Then, the area or length of each lesion and the
98 identification board width were measured using the ImageJ 1.49p software (Schindelin et al.,
99 2012). This software calculated length and area in pixels. In order to transform the lesion size
100 data (length of WLD lesions and area of SH or SU lesions) to millimetres, the identification
101 board width was used as a reference to adjust the size data to account for small variations in
102 camera distance from the foot. Data were transferred to an Excel® Lesion Scoring Input Form
103 (developed by RN), where the location of each lesion was added (Figure 1).

104 Zones of the sole were identified following the map described by Greenough and Vermunt
105 (1991) (Figure 1-A). Information on the presence or absence of heel horn erosion (i.e.
106 irregular horn surface with or without deep horn grooves that may expose the corium), double
107 sole (i.e. horn is separated at the grooves and formed a flap at the bulb of the heel as it has

108 two or more layers of under-run sole horn) and interdigital hyperplasia was recorded (ICAR,
109 2015).

110 The intra-observer reliability to measure correctly the lesions was assessed through measuring
111 the outline of a claw at the beginning and at the end of the picture session on three occasions
112 though out the study. The intra-observer reliability for the lesion identification was tested
113 using the same series of 25 pictures of lesions assessed at each of four testing sessions.
114 Images were presented in a random order at each session. These four sessions were prior to
115 commencing, twice during and at the end of the picture observations.

116 *Statistical analysis*

117 Descriptive analyses and reliability analysis were carried out using Stata/SE 12.0 (Stata Corp
118 2011, USA). The weighted kappa (k_w) was used to calculate the intra-observer reliability for
119 lesion scoring and the interpretation of the k_w was conducted using Landis and Koch (1977).
120 Area for each lesion severity category was not normally distributed, so the Kruskal Wallis
121 test was used to compare severity categories for each lesion type (Petrie and Watson, 2006).
122 A P-value of ≤ 0.05 was considered as significant.

123 A multilevel logistic regression model was built using MLwiN version 2.27 (Rasbash et al.,
124 2009). The two level (claw within cow) model examined if claw horn lesions type area and
125 presence (yes or no) affected the likelihood of recovery. Fixed effects included farm, cow ID,
126 limb of foot treated (right or left), claw (lateral or medial), recovery at 2 weeks (a binary
127 outcome), mobility score before treatment, one claw affected, lesion type (Table 1) present
128 (yes or no), area/length measurement and frequency for each lesion type, HHE (yes or no) and
129 double sole (yes or no). An additional variable was included to distinguish between operators
130 at the time of treatment (categorised as either the primary operator or other operators). Data
131 for severity category for each type of lesion was not included in the final model, this data was

132 consolidated to obtain a total area and frequency per claw horn lesion type to evaluate the
133 main aim of the study.

134 Results from the model are presented as odd ratios (OR) and confidence intervals [CI].
135 Frequency and presence of claw horn lesions by type showed high collinearity, therefore only
136 the presence of claw horn lesions by type variables was kept in the final model.

137 **RESULTS**

138 *Reliability of lesion identification*

139 The intra-observer overall average K_w agreement for lesion classification was very high $K_w =$
140 0.87 (95% CI: 0.75-0.96) with a range of 0.64 – 1.00. When measuring the same claw 6
141 times, the standard deviation was on average 3% of the mean of each measurement assessed
142 (range 1.38% - 7.18%).

143 *Animals*

144 Data from 143 cows were available for analysis, of which 11 became lame on a different leg
145 two weeks after treatment, 6 were diagnosed with DD, and pictures from 7 cows were
146 excluded because image quality was too poor or they were ambiguously identified. The final
147 dataset consisted of images of 238 claws from 119 cow lameness events.

148 *Prevalence and description of claw horn lesions*

149 One hundred and twelve cows were diagnosed with claw horn lesions (seven cows had no
150 visible lesions). Lesion prevalence varied according to claw: three cows had SH lesions on
151 both claws, three cows had WLD on both claws (haemorrhage and separation), 51 cows had
152 both claws affected by different combinations of lesions, and the remaining 55 cows had
153 different combinations of lesions by claw (e.g. one claw with SH and the other claw with a
154 SU).

155 SH was the most frequently observed lesion; 216 lesions were observed, predominantly on
156 the lateral claw (Table 2). WLH was the second most frequently observed, followed by WLS
157 (Table 2). SU were the least frequent claw horn lesion observed, with a total of 47
158 observations most of them located on the lateral claw.

159 *Claw horn lesions and recovery 2 weeks after treatment*

160 The recovery rate from lameness 2 weeks after therapeutic hoof trimming was 79.8% (n=95
161 cows). Results from the final model showed that only WLH lesions had a significant impact
162 on the likelihood of recovery from lameness. Recovery of cows with WLH was positively
163 associated with the length of the lesion (OR: 0.11 [0.03-0.42], Table 3). Cows assigned a
164 mobility score of 3 at the time of treatment were significantly less likely to recover compared
165 to cows with mobility score 2 (OR: 0.06 [0.01-0.54], Table 3), and cows with a single claw
166 affected were significantly less likely to recover than those with both claws affected (OR:0.37
167 [0.15-0.93]). Hoof trimming operator had a significant effect on the likelihood of recovery,
168 animals treated by the primary operator were more likely to recover. There was no significant
169 effect of other type of lesions on the likelihood of recovery.

170 *Association between size of lesions and categorical descriptors of severity*

171 The mean measured SU area categorised as mild was significantly greater than the area
172 categorised as severe (H=4.6, 1d.f.; P= 0.0001) (Figure 2). The mean measured SH area
173 categorised as mild was significantly greater than the areas categorised as both moderate and
174 severe (H=91.02, 2d.f.; P= 0.0001) (Figure 2). Similarly, the mean WLH and WLS lengths
175 categorised as mild were significantly longer than the lengths categorised as moderate and
176 severe (WLH: H=40.2, 2d.f.; P= 0.0001; WLS: H=7.6, 2d.f.; P=0.0001) (Figure 2).

177 **DISCUSSION**

178 The presence of WLH at the time of treatment decreased the likelihood of recovery from
179 lameness following a therapeutic trim. White line lesions have been linked to both milk loss
180 and lameness (Amory et al., 2008; Barker et al., 2007). Interestingly, the length of WLH was
181 positively correlated with the likelihood of recovery i.e. cows with longer lesions were more
182 likely to recover from lameness 2 weeks after treatment. It is possible that the haemorrhage
183 observed at the white line was caused several weeks before and the lesions observed were the
184 vestiges of more severe damage (Flower and Weary, 2006). Alternatively, mild white line
185 haemorrhage lesions were significantly larger than the other severity categories of WLH;
186 longer lesions were more likely to be mild, which could be more likely to recover. It is hard to
187 compare these results with previous studies, which often have not discerned between white
188 line haemorrhage and white line separation (Blackie et al., 2013; Chapinal et al., 2009). To
189 the author's knowledge, this is the first study to report associations between lesion type at the
190 time of treatment and the likelihood of recovery. The results can provide useful prognostic
191 information for clinicians and foot trimmers treating lesions in the field.

192 Sole haemorrhage has commonly been reported as the most prevalent lesion in similar work
193 (Groenevelt et al., 2014; Leach et al., 2012); the current study agrees with these findings. Sole
194 haemorrhage lesions were the largest of all lesions identified in this study. In a previous
195 study, sole haemorrhages was not associated with poor locomotion score (Flower and Weary,
196 2006), on the other hand SU have been strongly associated with poor locomotion score even 4
197 weeks before diagnosis (Chapinal et al., 2009). In this study 47, of the 286 claws observed,
198 were diagnosed with SU; though, most claws/ feet in this study displayed a combination of
199 lesions. Therefore, it is difficult to make comparisons between studies as some combine all
200 the lesions observed per foot or have only considered moderate to severe lesions in their
201 results (Chapinal et al., 2009; Tadich et al., 2010).

202 Most of the lesions observed were classified as mild and were also the largest lesions,
203 regardless of the type. As suggested by Groenevelt et al. (2014), it is possible that these
204 lesions may have been previously underreported. Cows in the present study became lame
205 within the previous 2 weeks before treatment. The fact that animals were lame suggests that
206 there could have been trauma at the level of the corium manifested through the presence of
207 haemorrhages, which may predispose to more serious lesions if left untreated or allowed to
208 progress (Groenevelt et al., 2014; Sogstad et al., 2007b). Most of the claw horn lesions were
209 observed in the lateral claw, in concurrence with previous work (e.g. Ahrens et al., 2011) and
210 has been explained by the anatomical and loading differences between digits (Van der Tol et
211 al., 2002).

212 It is interesting to observe that severity of a lesion was inversely proportional to size, which
213 was true for every claw horn lesion type observed. This might be caused by how the pressure
214 forces in the corium are distributed. When forces are distributed over a large area, the
215 pressure at an specific site is lower than when the forces are distributed over a small area,
216 causing less pressure therefore less lameness (Van der Tol et al., 2002). On the other hand, the
217 descriptors used in the present study were developed by the authors, based on descriptors
218 reported previously (Leach et al., 1998; Sogstad et al., 2005). Descriptors reported previously
219 have not included size; they have been based solely on the appearance of lesions. The work
220 reported here suggests that lesion size may well be an important aspect of lesion
221 pathogenicity. Future studies investigating lesion type and severity should include the area of
222 the lesion as part of the analysis as this may be of biological importance. Further work is
223 needed to investigate how the combination of area and severity and lesion type and severity
224 impact on recovery (the analysis employed in this study did not allow both lesion type and
225 lesion severity to be included in the final model).

226 Lamé cows that were lameness score 3 (severly lame) before treatment were less likely to
227 recover than those that were score 2 (mildly lame). Score 3 cows did not have a particular
228 lesion, all animals had different combinations of lesions per claw. Whay et al. (1997)
229 observed that lameness severity was positively associated with an increase in sensitivity to
230 mechanical noxious stimuli. This hyperalgesia persisted for at least 28 days after the lameness
231 was treated (Whay et al., 1998). Then, it is possible that these animals may have been in a
232 higher hyperalgesic state making them less likely to recover sooner in comparison to cows
233 that were score 2. This finding must be taken into consideration by the industry as additional
234 care should be taken when treating cows which are severly lame. Specifically, operators
235 treating lame cows should consider the administration of NSAIDs not to only more severly
236 lame cows, but to all lame cows when they are treated (Thomas et al., 2015).

237 Cows with one claw affected were less likely to recover. There were 28 cows with a single
238 claw affected, from these only 8 cows had a single type of lesions, the remaining 20 cows had
239 different combinations of claw horn lesions. In addition, 24 cows had lesions on the lateral
240 claw and 4 on the medial claw. Van der Tol et al. (2002) observed that the lateral claw of the
241 hindlimbs bears more weight than the medial claws when cows are standing even after
242 trimming. Consequently it may be more difficult to remove pressure from the lateral claw
243 using corrective trimming alone, which could explain the delayed recovery in these animals.

244 The recovery rate two weeks after treatment was 79%, which is similar to that observed by
245 Leach et al. (2012): in their study approximately 75% of the newly lame cows recovered 2
246 weeks after treatment. A prompt intervention is more likely to encounter mild lesions that are
247 less complicated to treat, increasing the chances of a rapid recovery and consequently less
248 lameness in the following lactations (Groenevelt et al., 2014). It is possible that the type of

249 lesion and its severity, measured by area or frequency, might not be as important as the early
250 diagnosis and treatment of these lesions.

251 Animals in the present study were treated using the 5 step Dutch Foot Trimming technique
252 (Toussaint-Raven et al., 1985). Previous research has suggested that foot trimming may cause
253 pain and discomfort (Chapinal et al., 2010; Van Hertem et al., 2014). None of these previous
254 studies specified which hoof trimming technique was used. Findings from the present study
255 suggest that following a standard technique, a good recovery rate can be achieved in newly
256 and predominantly mildly lame cows. There is little research on hoof trimming techniques
257 and their impact on recovery rates; further work is urgently required to understand how
258 different hoof trimming techniques influence recovery. In this study, case selection was
259 limited to cases of newly lame cows with only one hind limb affected with a claw horn lesion.
260 This enabled our case definition to be precise, but means that care should be taken when
261 generalizing our findings to the wider population.

262 **CONCLUSION**

263 Cows that were severely lame at the time of treatment, with one claw affected and with white
264 line haemorrhage were less likely to have recovered from lameness 2 weeks after treatment.
265 In addition, cows with longer white line haemorrhage are more likely to recover; this may be
266 linked to the severity of the lesion, because larger lesions tended to be less severe. Further
267 work is needed to better understand the factors that influence recovery from lameness
268 following treatment, to maximize recovery and limit the welfare impacts of this painful and
269 self-perpetuating disease.

270 **CONFLICT OF INTEREST STATEMENT**

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

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- 357

358 **Table 1** Classification and description of claw horn lesions used in a study to investigate the
 359 effect of claw horn lesion type at the time of treatment on recovery.

Type of lesion	Classification	Description
No Lesion		No claw horn lesion or any other lesion identified on the foot.
Sole Ulcer	Mild	Small penetration of sole surface, corium not expose 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 coloration at any location on the sole.
	Moderate	Presence of dark pink coloration at any location on the sole.
	Severe	Presence of very dark red or purple coloration at any location on the sole.
White Line Haemorrhage	Mild	Presence of diffuse light pink and/or yellow coloration at any location on the white line.
	Moderate	Presence of dark pink coloration at any location on the white line.
	Severe	Presence of very dark red or purple coloration at any locations on the white line.
White Line Separation	Mild	Dark coloured marks in the white line at any location.
	Moderate	Deep fissures and/or impacted areas in the white line at any location.
	Severe	Very deep or profound fissure, with the corium involved and/or purulent exudate, necrosis, granulation tissue and /or separation of wall and sole at any location.

360

361 **Table 2** Distribution of claw horn lesion type by severity across 112 cows in a study
 362 investigating lesion type at the time of treatment on recovery. Percentages of lesions by
 363 severity and by type are in parentheses.

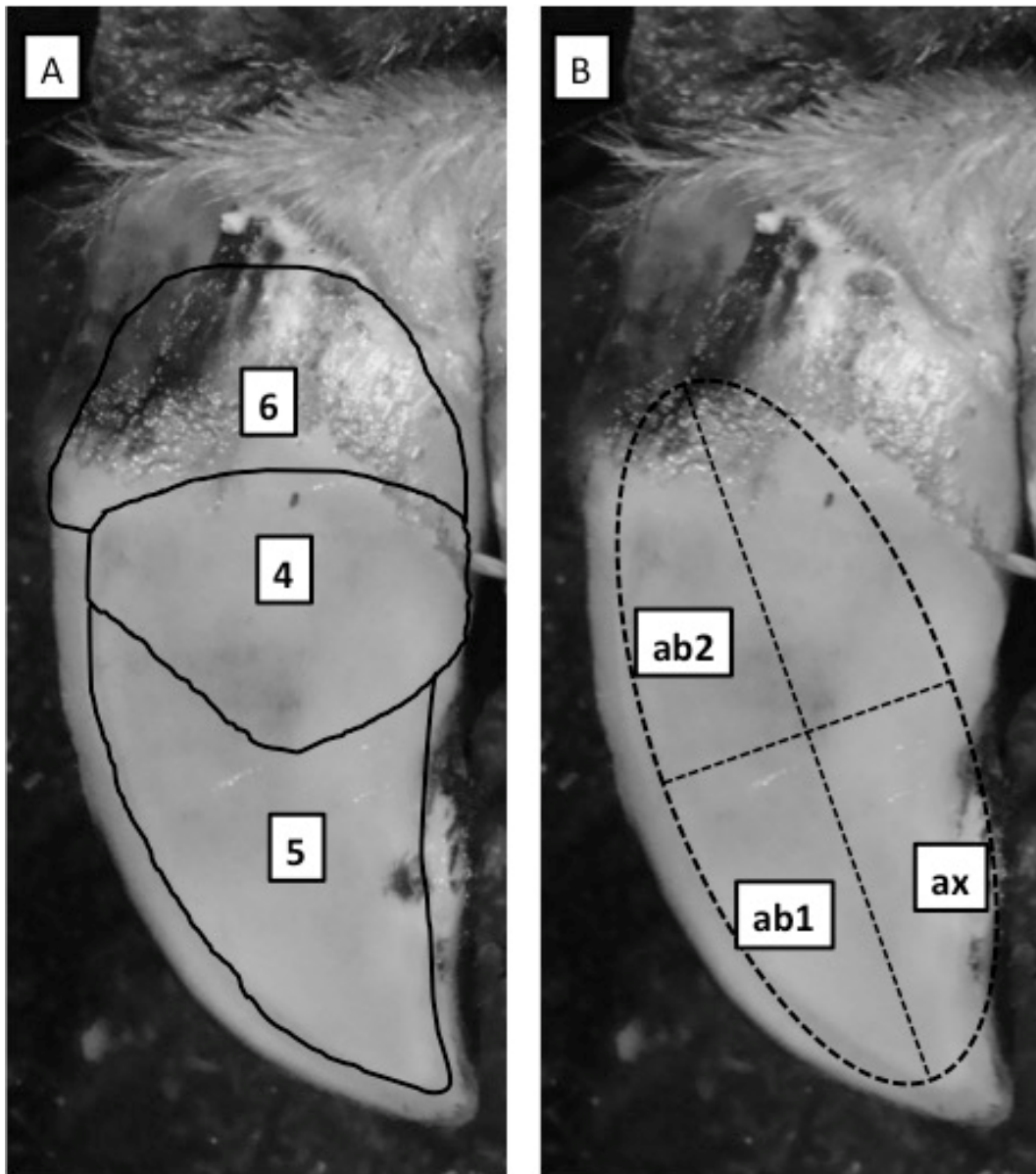
Lesion Type	Classification (Severity)	Lateral Claw	Medial Claw	Total by severity	Total by Lesion
Sole Ulcer	Mild	25 (67.6)	12 (32.4)	37 (78.7)	47 (100.0)
	Severe	8 (80.0)	2 (20.0)	10 (21.3)	
Haemorrhage	Mild	87 (68.5)	40 (31.5)	127 (60.5)	210 (100.0)
	Moderate	36 (63.2)	21 (36.8)	57 (27.1)	
	Severe	18 (69.2)	8 (30.8)	26 (12.4)	
White Line Haemorrhage	Mild	47 (54.7)	39 (45.3)	86 (64.6)	133 (100.0)
	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 (100.0)
	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 (100.0)
Under run		10 (40.0)	15 (60.0)		25 (100.0)

364

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

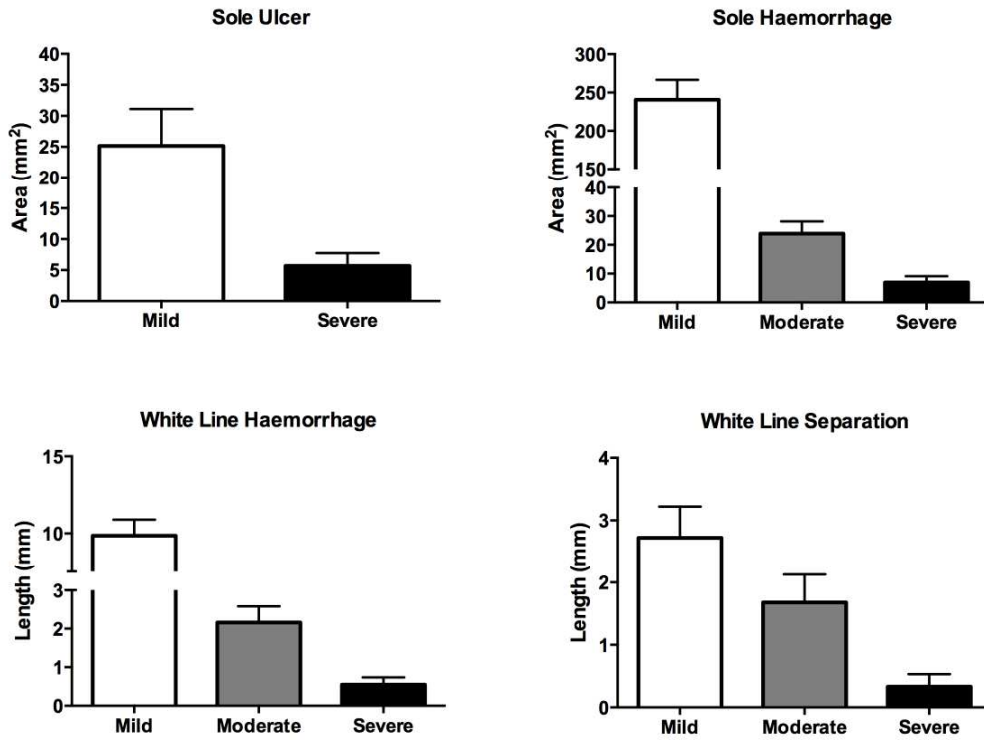
Model term	Freq ¹	Coef ²	SE	OR	z	Confidence Interval		P-value
						2.5%	97.5%	
Intercept		2.13						
Farm								
Farm 1	48	Reference						
Farm 2	38	0.29	0.65	1.33	0.19	0.37	4.78	0.66
Farm 3	6	-0.47	1.15	0.62	0.17	0.07	5.91	0.68
Farm 4	58	0.73	0.61	2.08	1.45	0.63	6.89	0.23
Farm 5	88	0.38	0.59	1.46	0.41	0.46	4.61	0.52
Mobility score at treatment								
MS 2	228	Reference						
MS 3	10	-1.93	0.91	0.15	4.49	0.02	0.9	0.03
Cow with one claw affected								
No	182	Reference						
Yes	56	-1.00	0.47	0.37	4.50	0.15	0.93	0.03
Operator								
Operator 1	216	Reference						
Operator 2	22	-1.68	0.61	0.19	7.57	0.06	0.62	0.01
Sole Ulcer								
Area (mm ²)	238	-0.006	0.004	0.99	2.25	0.99	1.00	0.13
Presence								
No	194	Reference						
Yes	44	0.96	0.85	2.61	1.28	0.50	13.70	0.26
Sole Haemorrhage								
Area (mm ²)	238	0.001	0.001	1.00	1.00	1.00	1.00	0.32
Presence								
No	92	Reference						
Yes	146	-0.09	0.46	0.92	0.04	0.37	2.26	0.85
White line haemorrhage								
Length (mm)	238	0.05	0.02	1.05	4.80	1.00	1.09	0.03
Presence								
No	137	Reference						
Yes	101	-2.20	0.68	0.11	10.45	0.03	0.42	0.001
White line separation								
Length (mm)	238	-0.03	0.03	0.98	0.69	0.92	1.03	0.40
Presence								
No	188	Reference						
Yes	50	0.54	0.89	1.71	0.36	0.30	9.84	0.55
Heel horn erosion								
No	169	Reference						
Yes	69	-0.44	0.56	0.65	0.62	0.22	1.93	0.43
Double sole								
No	213	Reference						
Yes	25	-0.04	0.68	0.96	0.00	0.25	3.61	0.95

¹Frequency of observations; ²Coefficient



368

369 **Figure 1** Zones of the distal surface of the claw used to describe location of claw horn lesions
 370 observed in a study investigating the effect of lesion type at the time of treatment on recovery.
 371 Figure 1-A shows zones for sole ulcers and haemorrhage 4= sole, 5= toe, 6= heel. Figure 1-B
 372 shows zones for white line lesions ab1= abaxial wall zone 1, ab2= abaxial wall zone 2, and
 373 ax= axial wall (Modified from Leach et al., 1998). White line zones were defined using
 374 anatomical features as follows: an ellipse was drawn on the sole area of each picture, the
 375 limits of the main long ellipse axis where the outer edge of the white line at the corner of the
 376 toe and the caudal extremity of the white line at the heel. Then, the abaxial border of the
 377 ellipse was extended to meet the abaxial white line. This gave three areas: abaxial 1, abaxial 2
 378 and axial that allowed for consistency between pictures.



379

380 **Figure 2** Distribution of area/length and standard error of each claw horn lesion type
 381 measured on pictures by severity scored on a categorical scale in a study investigating lesion
 382 type at the time of treatment on recovery.

383