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Hoof lesions in partly housed pasture-based dairy cows

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ABSTRACT

Lameness is a symptom of a painful disorder affecting the limbs, which impacts dairy cow welfare and productivity. Lameness is primarily caused by hoof lesions. The prevalence of different lesion types can differ depending on environmental conditions and farm management practices. The aims of this observational study were to establish the cow-level and herd-level lesion prevalence during both housing and grazing periods in a partly housed, pasture-based system, establish the prevalence of lesions always associated with pain ("alarm" lesion), identify the lesions associated with a higher lameness score, determine relationships between lesions, and identify risk factors for digital dermatitis. On 98 farms during the grazing period and on 74 of the same farms during the housing period, every cow was lameness scored (0–3 lameness scoring scale), and the hind hooves of lame cows (score 2 and 3) were examined (maximum 20 cows per visit) and the prevalence of each lesion type recorded. To gather data on potential predictors for the risk factor analysis, a questionnaire with the farmer was conducted on lameness management practices and infrastructure measurements were taken at each visit. Cow-level data were also collected (e.g., parity, breed, milk yield, and so on). Noninfectious lesions were found to be more prevalent than infectious lesions in this system type. The most prevalent lesion types during both grazing and housing periods were white line separation, sole hemorrhages and overgrown claws; all remaining lesions had a cow-level prevalence of less than 15%. The cow-level prevalence of alarm lesions was 19% during the grazing period and 25% during the housing period; the most prevalent alarm lesion was sole ulcers during both periods. We found significantly more foreign bodies within the hoof sole (grazing = 14%, housing = 7%) and overgrown claws (grazing = 71%, housing = 55%) during the grazing period compared with the housing period. Cows with foul of the foot, sole ulcer, white line abscess, toe necrosis or an amputated claw had higher odds of being more severely lame, compared with mildly lame. The strongest correlation between lesions were between toe necrosis and digital dermatitis (r = 0.40), overgrown claws and corkscrew claws (r = 0.33), and interdigital hyperplasia and digital dermatitis (r = 0.31) at herd level. At the cow level, the strongest correlation was between overgrown claws and corkscrew claws (r = 0.27), and digital dermatitis and heel erosion (r = 0.22). The farmers' perception of the presence of digital dermatitis (and lameness) was significantly correlated with the actual presence of digital dermatitis recorded. Additional risk factors for the presence of digital dermatitis were cow track and verge width near the collecting yard, and stone presence on the cow tracks. Results from this study help further our understanding of the causes of lameness in partly housed, pasture-based dairy cows, and can be used to guide prevention and treatment protocols.
Key words: dairy cow, lameness, hoof lesions, pasture-based

INTRODUCTION

Lameness in dairy cattle is a global problem within the dairy industry resulting in financial, environmental, and animal welfare issues. Lameness is the result of a painful disorder (Coetzee et al., 2017), leading to reduced productivity (Green et al., 2002; Alawneh et al., 2011), increased risk of culling (Booth et al., 2004), and increased greenhouse gas emissions (Chen et al., 2016; Mostert et al., 2018). Bovine lameness is most commonly caused by the presence of hoof lesions (Murray et al., 1996).

Due to environmental differences, the prevalence of different lesion types varies between housed and pasture-based systems (Navarro et al., 2013; Somers and O'Grady, 2015; Solano et al., 2016). The majority of studies report that infectious lesions are the most common lesion type in fully housed dairy cows (Cramer

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et al., 2008; Solano et al., 2016). Digital dermatitis is thought to be spread mostly via slurry (Palmer and O'Connell, 2015), and housed systems tend to expose cows to this more compared with pasture-based systems (Somers and O'Grady, 2015).

There are only a limited number of publications on hoof lesion prevalence in partly housed, pasture-based dairy systems, such as those in Ireland, some in the United Kingdom, and some other regions of Europe, where cows are grazed for the majority of the year and housed for a few months over the winter period. This system is prominent in temperate areas, where grass can be used as the main feed source for most of the year, keeping concentrate input low (Dillon et al., 1995). In this system type, spring calving is common to allow peak milk production to coincide with maximum grass growth (Dillon et al., 1995). This system is uniquely different to the typical pasture-based system, such as that in New Zealand and Chile, where the majority of herds are grazed year-round; however, the partly housed, pasture-based dairy system may still be applicable to a proportion of dairy herds in these countries where cows are housed over the winter period. Interest in grass-fed dairy systems has increased worldwide as consumers are beginning to perceive this system type as more sustainable and animal welfare friendly than more intensive housed systems, providing marketing advantages globally (Moscovici Joubran et al., 2021). Currently, few dairying nations have the climate required to make out-wintering the entire year a sustainable option; therefore, this system of grazing cows for the majority of the year and housing cows for a few months over the winter period may become a sustainable option for dairy farmers around the world in the future.

A previous study reported that the most common lesion types in lame [lameness score (**LS**) 3, 4, or 5 on a 1–5 scale] partly housed, pasture-based dairy cows were white line disease (separation with or without abscess) and sole hemorrhages (Somers and O'Grady, 2015). However, this study had a relatively small sample size of 10 herds, which were part of a herd-health program; therefore, these results may not be representative of the general population of dairy cows in a partly housed, pasture-based system. Widening of the white line was also found to be common in Switzerland where cows had frequent pasture access (Becker et al., 2014). Navarro et al. (2013) also reported that white line separation was the most prevalent lesion type in lame cows (LS3 on a 1–5 scale) at pasture.

Although infectious lesions have historically been less commonly reported in pasture-based dairy systems than in housed systems, Browne et al. (2022a) reported that the presence of farmer-reported digital dermatitis in the herd increased the odds of lameness in part-housed, part-grazed dairy herds. Digital dermatitis has also been reported as the most prevalent of all infectious lesion types in a partly housed, pasture-based system (Somers and O'Grady, 2015). It would, therefore, be beneficial to determine the risk factors for digital dermatitis in partly housed, partly grazed dairy cows.

Lesion type can influence the ability of the cow to bear weight on the affected hoof, therefore altering the severity of lameness. A study on a single dairy farm in the United Kingdom reported that changes in gait, including a shortened stride, were greater in cows who had a sole ulcer compared with other lesion types (Blackie et al., 2013). Tadich et al. (2010) identified that sole ulcers, double sole, and interdigital hyperplasia were associated with a cow being more severely lame. In this study, cows were either grazed year-round or partially during the year.

Understanding the relationship between lesions can increase our understanding of the underlying causes of lameness and, therefore, improve treatment. Understanding lesion relationships will also help establish lesions with the same and similar causative mechanism, or lesions which have shared risk factors. In addition, it may also identify if a secondary lesion forms following a different lesion. Manske et al. (2002) reported that the strongest correlations at both cow and herd level were between heel erosion and digital dermatitis, between abnormal claw shape and sole ulcers, and between sole and white line hemorrhages. This study also demonstrated that most hoof lesions that affected one back hoof also affected the corresponding back hoof (Manske et al., 2020). To the best of our knowledge, no studies have looked at the relationship between lesion types in partly housed, pasture-based herds for both the grazing and housing seasons.

Investigating the hoof lesions present in partly housed, pasture-based dairy cows will increase our understanding of the etiology of the disease and provide direction to farmers, veterinarians, and advisors on where to focus lesion prevention and treatment in this unique system type. Therefore, the aims of this large-scale study were to (1) determine the cow-level and herd-level prevalence of each lesion type during both the grazing and housing periods in lame partly housed, pasture-based dairy cows, (2) establish the prevalence of lesions always associated with pain (alarm lesion), (3) identify which lesions were associated with a higher lameness score, (4) establish the relationship between lesions, and (5) identify the risk factors for digital dermatitis for lame cows in a partly housed, pasture-based dairy system.

MATERIALS AND METHODS

The Teagasc Animal Ethics Committee (Cork, Ireland) granted ethical approval prior to the start of the study (TAEC202-2018). Data for this study were collected as part of a larger investigation exploring dairy cow welfare and lameness in partly housed, pasture-based systems (Crossley et al., 2021; Browne et al., 2022a,b). A detailed description of the study method is provided by Browne et al. (2022a). In brief, 102 dairy farms in Ireland were visited during the 2019 grazing period (April 2019–September 2019), and 87 of these farms were revisited during the subsequent housing period (October 2019–February 2020). For farms visited during both periods, the median number of days between visits was 167 d [interquartile range (**IQR**) = 12–220]. The median herd size of all farms included in the analysis was 117 (IQR = 80–156). The median total distance cows walk between the collecting yard and pasture across all farms included in the analysis was 1,900 m/d (IQR = 1,200–2,400). All farms had cubicle (stall) housing, and a small proportion had additional loose housing. The majority of cubicles had a mat with no bedding present. The most common flooring type across farms was grooved concrete, smooth concrete, and smooth concrete slats.

At each visit, the entire milking herd was lameness scored using a 0 to 3 scale (AHDB, 2020a) and a proportion of the herd was body condition scored (1 to 5 scale, in 0.25 increments; AHDB, 2020b) based on the Welfare Quality sample size protocol (Welfare Quality Consortium, 2009). This ranged from 100% of the herd being scored for a herd size of 30 cows, to 28% of the herd being scored for a herd size of 250 cows. Training in body condition scoring and lameness scoring was carried out with all observers before farm visits starting. Interobserver reliability tests were carried out at the start of each visit period, ensuring consistency among scorers; additionally, all kappa coefficients were greater than 0.7. Infrastructure measurements (Browne et al., 2022a) were taken at the milking facilities (parlor and collecting yard), housing facilities (straw yards and cubicle housing), and cow tracks. Examples of cow track measurements taken were track width, verge width, and the presence of loose stones (measured by recording the number of the 25 squares within a quadrat that contained stones). Cow track measurements were taken within the first 50 m section from the collecting yard entrance for all cow tracks used by dairy cows, and on the cow track that was in use during the grazing visit at the half-way point between the collecting yard entrance and paddock entrance, end-point of the cow track, and paddock gateway. A questionnaire with the farmer was also completed at each visit (questions asked to the farmer by the researcher) to identify background information (e.g., herd size and distance cows walk between the collecting yard and pasture each day), farm management protocols and lameness prevention (e.g., proportion of farmers that footbath), detection, and treatment methods used; moreover, each questionnaire can also be viewed as supplementary material (Browne, 2021). Routinely recorded herd management data (e.g., breeding events and milk yields) were provided by the Irish Cattle Breeding Federation.

Hoof Examination

The hooves of up to a maximum of 20 lame cows (LS2 and LS3) were examined per visit. When more than 20 cows were scored as lame, random selection of cows was stratified by LS (e.g., if 15% of the herd had a LS2 and 5% of the herd had LS3, then 15 LS2 and 5 LS3 cows would be selected at random from the ID of cows in each category). A similar selection method was previously used by Tadich et al. (2010). Hoof trimming was performed by a professional hoof trimmer from the Farm Relief Service (Roscrea, Co. Tipperary, Ireland), and cows were examined by 1 trained observer per visit (from a pool of 5 observers in total) to diagnose and record lesions. All observers were trained in lesion identification at a hoof trimming course or by an observer who attended the hoof trimming course. Due to time constraints, only the hind hooves were examined; however, if the cow was noticeably lame on a front hoof during scoring, this hoof was treated as required (data not included in analysis).

During each hoof examination, the longest claw was measured from where the claw goes hard (distal limit of perioplic horn) to the tip of the toe to determine whether the hoof was overgrown, before any removal of horn. Claws with a dorsal wall length over 80 mm were classified as overgrown (AHDB, 2017). Next, a thin layer of horn was removed (~1 mm) to clean the hoof, as done in previous hoof health studies (Vanegas et al., 2006; O'Driscoll et al., 2008). This allowed lesions, such as mild white line separation, which may not be apparent after a full trim, to be identified. The trimmer subsequently trimmed the hoof using the 5-step Dutch hoof trimming method (Toussaint-Raven, 1985). The presence and number of each lesion type were recorded for each back hoof using a paper recording sheet. The majority of lesions were recorded after the cleaning of the hoof; however, if additional hoof lesions became apparent during the trimming process, these lesions were also recorded. A guide with photographs was used to ensure the 5 trained observers remained consistent when recording lesion types throughout the study; specifically, this included the infectious lesions digital dermatitis (meaning the lesion characteristic of the disease digital dermatitis), foul of the foot (interdigital phlegmon), and heel erosion, as well as the noninfectious lesions double sole, fissures (axial, horizontal, vertical), foreign body, hoof abscess, interdigital hyperplasia, sole hemorrhage, sole ulcer, toe necrosis, white line abscess, and white line separation. Claw deformations (overgrown claw and corkscrew claw) were also recorded, as well as the presence of digit amputation; for analysis, these were considered to be noninfectious lesions. The guide was created based on previous publications (Greenough and Vermunt, 1991; Döpfer et al., 1997; Leach et al., 1998; Berry et al., 2012) and from descriptions and images of lesions (for example, from the ICAR claw health atlas; ICAR, 2015).

Statistical Analysis

All statistical analysis was performed in R version 3.3.1 (R Core Team). Farms that were visited during both the grazing and housing period, as well as those only visited once during the grazing period, where in included in all analyses.

Cow-Level Lesion Prevalence

Descriptive analysis was first undertaken using the total number of each lesion type per lame cow. The presence or absence of each lesion type per lame cow was used for all further analyses. Cow-level lesion prevalence within lame cows was calculated for both the grazing and housing periods, defined as the number of lame cows with the lesion present divided by the total number of lame cows examined. Chi-squared (χ^2) tests for independence were used to compare cow-level lesion prevalence between grazing and housing, excluding lesions with a prevalence of less than 1%. The effect size was calculated using the phi coefficient (φ).

As adapted from Kofler et al. (2022), lesions always associated with pain were classified as "alarm" lesions, and in this study included foul of the foot, hoof abscess, M2 digital dermatitis (acute, ulcerative, and painful), sole ulcers, toe necrosis, and white line abscess. The cow-level prevalence of alarm lesions was calculated. The mean and maximum number of alarm lesions per cow, as well as the mean and maximum number of alarm lesion types per cow were also calculated.

Herd-Level Lesion Prevalence

The herd-level lesion prevalence within lame cows was calculated as the number of lame cows in the herd with each lesion present divided by the total number of lame cows examined in each herd, for both the grazing and housing visits. Proportion of herds affected was calculated for each lesion for both the grazing and housing visits as the number of herds with at least 1 affected lame cow with a particular lesion present divided by the number of herds examined.

Lesions Associated with a Higher Lameness Score

Logistic regression was performed at cow level with lameness severity as the binary outcome variable. The outcome of this model was impaired mobility (LS2) versus severely impaired mobility (LS3); specifically, LS2 was coded zero (negative outcome) and LS3 was coded one (positive outcome). The presence of each lesion type were the binary predictors. Predictors were checked for over-dispersion and multicollinearity. Farm was included in the model as a random effect. The final mixed effect logistic regression model was built via backward selection using Akaike information criterion.

The final parameter estimation was performed using the package 'brms' (Bürkner, 2017). Markov chain Monte Carlo (**MCMC**) methods were used to fit the model, and then the parameter estimate chains from the MCMC process were used to generate a predicted probability, with 95% confidence intervals, of each cow being scored a LS3 as opposed to a LS2. The MCMC method is a more reliable method of producing parameter estimates, compared with other methods such as maximum likelihood estimation (Browne and Draper, 2006). The probabilities were grouped into predicted risk deciles and compared with the observed proportion in the corresponding group. Model fit was judged acceptable where the observed proportion was situated within the predicted risk 95% confidence interval for each group. Odds ratios (**OR**) were calculated from model coefficient estimates, and full posterior predictions were used to assess model fit.

Relationship Between Lesions

Correlations between lesion types, using data from both the grazing and housing period, were analyzed at cow level using the phi coefficient (φ) and at herd level using Spearman's rank correlation coefficient. At cow level, binary scores were used, whereas the prevalence of each lesion was used at herd level. Correlation coefficients between lesions are displayed as a heat-map, whereby the magnitude of the coefficients is represented as colors.

Risk Factors for Digital Dermatitis at Herd Level

Factors included in the risk factor analysis included data from the Irish Cattle Breeding Federation (cow-level data), farmer questionnaires, and infrastructure measurements. To create a herd-level data set, dummy variables were created from all cow-level categorical predictors, such that each categorical variable was converted to multiple variables, each representing the proportion of cows in the herd which fell into each category of the original categorical variable. Further, both dummy and continuous cow-level predictors were averaged across farm. To account for situations where cows were housed in multiple different environments on the same farm, housing predictors were weighted by the number of cows present in each pen. Using the 'missForest' package (Stekhoven, 2013), missing herd-level data from both questionnaires and infrastructure measurements were imputed via random forest algorithms (3.7% of data set). Twenty-three predictors were subsequently removed from the data set due to near-zero variance; thus, the final data set consisted of 209 predictors. All continuous predictors were centered and scaled using the 'preProcess' function within the 'Caret' package (Kuhn, 2020). Digital dermatitis presence was included in the data set for each farm at each visit.

Important risk factors for digital dermatitis were determined though triangulation (Lawlor et al., 2016; Lima et al., 2021) of elastic net regression (**Enet**) and logistic regression using modified Bayesian information criterion (**mBIC**). The same method was previously used to establish important risk factors for lameness; additionally, a more detailed description and discussion of the method used can be found in Browne et al. (2022a). In the current analysis, the outcome variable took a binary form (0 = no lame cows in the herd had digital dermatitis, 1 = minimum of 1 lame cow in the herd had digital dermatitis). Covariates from cow-level data, questionnaires, and infrastructure measurements were offered to the model. Bootstrapping (1,000 repeats) was implemented for both the Enet and mBIC models.

Bootstrap P-values (proportion of coefficients from the bootstrap repeats on the minority side of zero) and stability values (proportion of coefficients from the bootstrap repeats that were nonzero) were calculated for each predictor. Predictors were selected in each model if $P < 0.05$ and the stability value was ranked in the top 11. Eleven is the number of predictors with a stability >80% in the Enet model, a method previously used by Lima et al. (2020) and Browne et al. (2022a). Predictors that were selected in both the final Enet and mBIC models were deemed to have important associations to digital dermatitis. Further details on triangulation of Enet and mBIC and the use of bootstrapping can be viewed in Browne et al. (2022a).

RESULTS

To ensure farms represented the typical Irish dairy system (spring-calving, pasture-based, and twice a day milking through a conventional parlor), we excluded 3 farms from the grazing visit and 2 farms from the housing visit due to once-a-day or robotic milking. Any non-lame cows, heifers, or non-spring-calving cows accidentally hoof scored were also removed from the data set. Lame cows (LS2 and LS3) were drafted for hoof scoring a median of 3 d following the lameness scoring visit (range: 0–11 d). Hoof examinations were not possible on 1 farm during the grazing visit (6 cows) and on 10 farms during the housing visit (110 cows); therefore, these farms were not included in the analysis. This was due to the farmer not wanting the hoof trimming visit to take place, or the scorer or hoof trimmer being unable to attend the visit due to unforeseen circumstances. One farm during the housing period had no lame cows; therefore, no hoof examination was required. An additional 35 cows during the grazing period and 130 cows during housing period were not hoof scored due to the farmer not wanting the cow examined, the cow refusing to enter the trimming crate (chute), or the cow not being drafted. The main reason for the farmer not wanting the cow examined was due to injury or the cow being heavily pregnant. The final data set consisted of hoof examinations from 941 lame cows on 98 farms during the grazing period, and hoof examinations from 631 lame cows on 74 farms during the housing period.

Cow-Level Lesion Prevalence

The mean number of lesions per lame cow was 5.5 during the grazing period and 4.9 during the housing period. The maximum number of lesions for a single lame cow was 16 and 14 for the grazing and housing periods, respectively. The mean number of lesion types per lame cow was 3.1 for the grazing period and 3.0 for the housing period. During both periods, the maximum number of different lesion types for a single lame cow was 8. Using the alarm lesion concept proposed by Kofler et al. (2022), there was a mean of 0.2 alarm lesions per lame cow during the grazing period and 0.3 during the housing period. The maximum number of alarm lesions for a single lame cow was 4 and 3 for the grazing and housing periods, respectively. The mean number of alarm lesion types per lame cow was 0.2 for the grazing period and 0.3 for the housing period. The maximum number of different alarm lesion types for a single lame cow was 2 during the grazing period and 3 during the housing period. During the grazing period, 1.6% of lame cows had no lesions present on either hind

Table 1. Cow-level lesion prevalence for 941 lame, spring-calving, partly housed, pasture-based cows (98 herds) during the grazing period (Apr. 2019–Sep. 2019) and for 631 lame cows (74 herds) during the housing period (Oct. 2019–Feb. 2020)[1]

	Cow-level prevalence[2] (%)				
Lesion	Grazing period	Housing period	χ^2	P-value	φ
Sole hemorrhage	79.9	76.9	2.099	0.147	0.037
White line separation	72.4	73.2	0.137	0.712	0.009
Overgrown	71.1	55.3	41.241	<0.001	0.162[a]
Corkscrew claw	14.6	9.8	7.654	0.006	0.070
Foreign body	14.3	7.0	20.352	<0.001	0.114[a]
Digital dermatitis	12.4	13.2	0.176	0.675	0.011
Heel erosion	12.3	13.8	0.716	0.397	0.021
Interdigital hyperplasia	11.2	8.1	3.998	0.046	0.050
Sole ulcer	9.6	12.7	3.798	0.051	0.049
Double sole	6.5	9.8	5.854	0.016	0.061
Toe necrosis	3.7	5.4	2.500	0.113	0.040
White line abscess	3.4	6.4	7.463	0.006	0.069
Axial fissure	1.9	4.4	8.500	0.004	0.073
Foul of the foot	0.9	0.8	NT[3]	NT	NT
Horizontal fissure	0.4	0.2	NT	NT	NT
Digit amputation	0.3	0.2	NT	NT	NT
Hoof abscess	0.1	0.6	NT	NT	NT
Vertical fissure	0.0	0.0	NT	NT	NT

[a]$P < 0.05$ and $\varphi \geq 0.1$ [i.e., minimum effect size of "small" (Cohen, 1992)].

[1]Chi-squared tests for independence (χ^2) were used to compare lesion prevalence during the grazing and housing periods; the effect size was also measured using the phi coefficient (φ). The association was not tested if the lesion prevalence was <1% at either visit.

[2]Number of cows with lesion present/total number of cows examined × 100.

[3]NT = not tested.

hoof and 8.3% had lesions present on one hind hoof only. Similarly, during the housing period 1.7% of lame cows had no lesions present on either hind hoof and 9.8% had lesions present on one hind hoof only.

Cow-level lesion prevalence within lame cows are reported in Table 1. Noninfectious lesions were found to be most prevalent; specifically, 97.2 and 96.8% of lame cows had at least 1 noninfectious lesion during the grazing and housing periods, respectively. In comparison, 21.6 and 23.6% of lame cows had at least 1 type of infectious lesion during the grazing and housing periods, respectively. The cow-level prevalence of alarm lesions in lame cows was 19 and 25% during the grazing and housing periods, respectively. The most prevalent alarm lesion was sole ulcer during both the grazing and housing period. The most prevalent noninfectious lesions were sole hemorrhages, white line separation, and overgrown claws; additionally, all other noninfectious lesions had a prevalence of <15%. The most prevalent infectious lesions were digital dermatitis and heel erosion (Table 1).

At cow level, we found a significant difference in lame cows, with an effect size of ≥0.1, between the prevalence of foreign bodies during grazing and housing ($P < 0.001$), and between the prevalence of overgrown claws during grazing and housing ($P < 0.001$). We also found a significant difference between visits for axial fissures ($P = 0.004$), corkscrew claws ($P = 0.006$), double soles ($P = 0.016$), interdigital hyperplasia ($P = 0.046$), and white line abscess ($P = 0.006$); however, these had an effect size <0.1.

Herd-Level Lesion Prevalence

Herd-level lesion prevalence within lame cows are reported in Table 2. Similar to cow level, the herd-level prevalence of sole hemorrhages, white line separation, and overgrown claw were the most prevalent noninfectious lesions, and digital dermatitis and heel erosion were the most common infectious lesions. Sole hemorrhages, white line separation, and overgrown claws were also present in the largest number of herds. Foul of the foot, digit amputation, horizontal fissures, and hoof abscesses were diagnosed in <10% of herds (Table 2).

Lesions Associated with a Higher Lameness Score

The lesions associated with a higher LS in lame cows (LS2 vs. LS3) are shown in Table 3. The odds of a cow being scored as LS3 as opposed to LS2 was 15.01 times higher for lame cows that had previously had a claw

Table 2. Herd-level lesion prevalence (mean, standard deviation, minimum, and maximum) for lame cows in 98 spring-calving, partly housed, pasture-based herds during the grazing period (Apr. 2019–Sep. 2019) and in 74 of these herds during the housing period (Oct. 2019–Feb. 2020)[1]

	Grazing period					Housing period				
	Herd-level prevalence[2] (%)				Herds affected[3] (%)	Herd-level prevalence (%)				Herds affected (%)
Lesion	Mean	SD	Min	Max		Mean	SD	Min	Max	
Sole hemorrhage	81.0	20.7	0.0	100.0	99.0	77.2	26.3	0.0	100.0	97.3
White line separation	72.3	22.0	25.0	100.0	100.0	73.0	26.3	0.0	100.0	97.3
Overgrown	71.5	22.8	0.0	100.0	98.0	52.4	24.2	0.0	100.0	91.9
Corkscrew claw	15.5	19.6	0.0	83.3	56.1	9.3	11.9	0.0	40.0	47.3
Foreign body	14.0	16.0	0.0	75.0	62.2	6.2	9.9	0.0	50.0	37.8
Heel erosion	11.7	19.5	0.0	85.7	37.8	12.8	20.0	0.0	85.7	44.6
Interdigital hyperplasia	11.7	15.4	0.0	75.0	53.1	8.9	16.7	0.0	100.0	37.8
Digital dermatitis	10.1	18.3	0.0	80.0	34.7	9.5	16.9	0.0	75.0	35.1
Sole ulcer	8.5	11.5	0.0	60.0	49.0	10.7	12.7	0.0	50.0	55.4
Double sole	4.8	7.7	0.0	33.3	36.7	9.4	12.3	0.0	50.0	47.3
Toe necrosis	3.6	9.5	0.0	50.0	19.4	4.2	10.0	0.0	62.5	24.3
White line abscess	3.3	8.0	0.0	50.0	23.5	6.8	15.2	0.0	100.0	28.4
Axial fissure	1.7	5.2	0.0	28.6	12.2	5.0	10.4	0.0	50.0	28.4
Digit amputation	0.7	4.2	0.0	33.3	3.1	0.3	2.3	0.0	20.0	1.4
Foul of the foot	0.6	2.5	0.0	14.3	7.1	0.6	2.4	0.0	14.3	5.4
Horizontal fissure	0.3	1.7	0.0	15.4	3.1	0.2	1.9	0.0	16.7	1.4
Hoof abscess	0.1	1.4	0.0	14.3	1.0	0.3	1.3	0.0	6.3	5.4
Vertical fissure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[1]The percentage of herds affected by each lesion is also reported for each period.

[2]Number of cows with lesion on the farm/total number of cows examined on the farm × 100. Min = minimum; Max = maximum.

[3]Percentage of herds with at least one affected cow.

amputated. The odds of a cow being scored as LS3 compared with LS2 were 9.41, 4.70, 3.85, 2.03, and 1.68 times higher for cows with foul of the foot, white line abscess, sole ulcer, toe necrosis, or interdigital hyperplasia, respectively. However, the odds of a cow being scored as LS3 as opposed to LS2 was lower for cows with heel erosion (OR = 0.46).

Results from the full posterior prediction via MCMC, to indicate model fit, are shown in Figure 1. The mean observed outcome for each risk decile was within the 95% confidence interval of the predicted outcome, indicating good model fit.

Relationship Between Lesions

Correlations between cow- and herd-level lesion types are shown as a heat-map in Figure 2. At cow level, the strongest correlations were between overgrown claws and corkscrew claws, and between digital dermatitis and heel erosion. The strongest correlation at herd level

Table 3. Results from the multilevel logistic regression model to determine which lesions were associated with a higher lameness score in spring-calving, partly housed, pasture-based lame cows (i.e., lameness score of 3 rather than 2)[1]

Hoof lesion	Estimate	Lower 95% CI	Upper 95% CI	SE	Odds ratio	*P*-value
Intercept	−2.454	−2.809	−2.100	0.181		
Digit amputation	2.709	0.590	4.828	1.081	15.01	0.012*
Digital dermatitis	0.406	−0.103	0.915	0.260	1.50	0.118
Foul of the foot	2.243	1.031	3.454	0.618	9.41	0.000***
Heel erosion	−0.756	−1.360	−0.153	0.308	0.46	0.014*
Interdigital hyperplasia	0.520	0.019	1.020	0.255	1.68	0.042*
Overgrown	−0.344	−0.692	0.003	0.177	0.70	0.052
Sole ulcer	1.348	0.931	1.766	0.213	3.85	0.000***
Toe necrosis	0.712	0.032	1.392	0.347	2.03	0.040*
White line abscess	1.548	0.945	2.150	0.307	4.70	0.000***

[1]Scores from both the grazing period (98 herds; April 2019–September 2019) and the housing period (74 herds; October 2019–February 2020) were used in the analysis.

***Odds ratio is significantly different from 1 ($P < 0.001$).

*Odds ratio is significantly different from 1 ($P < 0.05$).

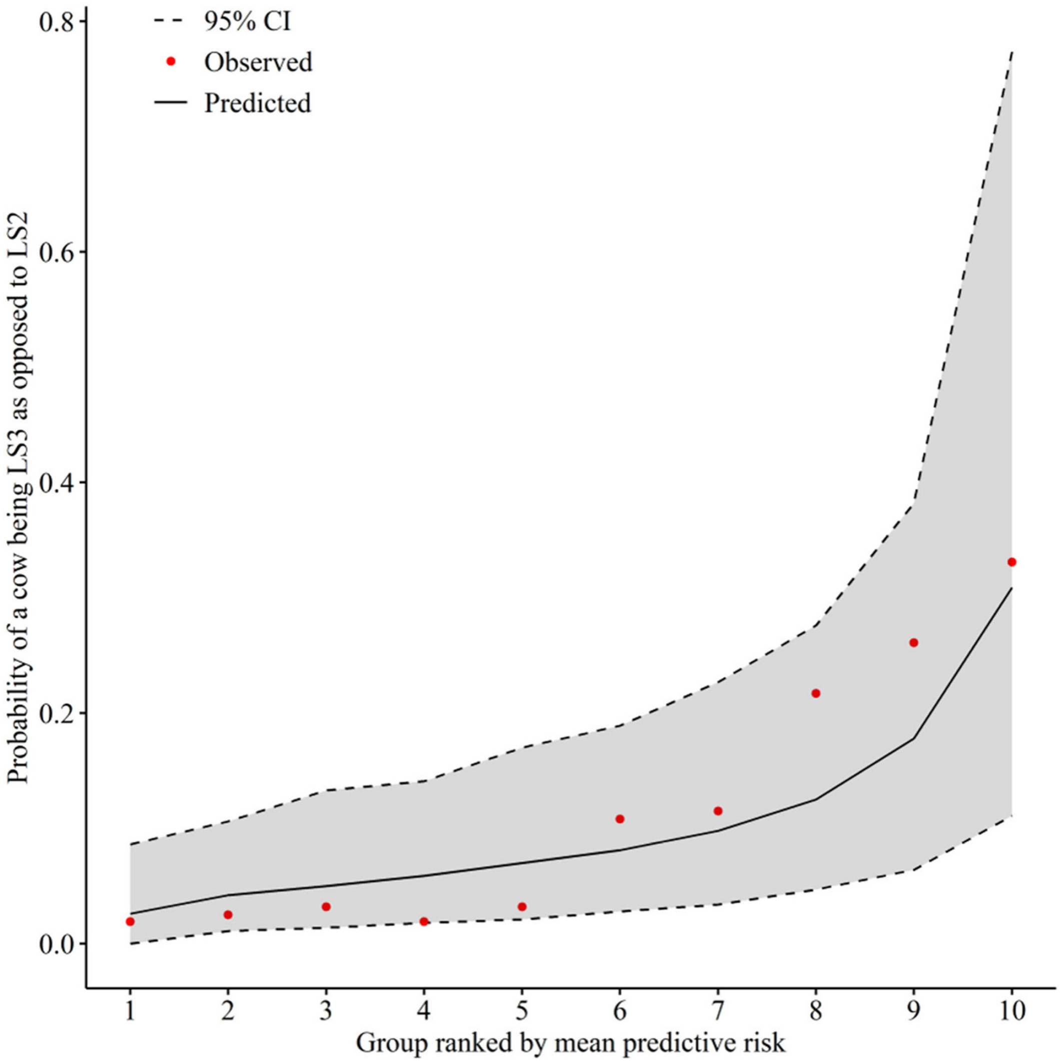

Figure 1. Predicted probability (and 95% CI) of a cow being scored a lameness score (LS) of 3 as opposed to a LS2 for each risk decile (groups ranked by mean predicted risk). Predicted probabilities were calculated via Markov chain Monte Carlo methods. Observed proportions of cows scoring a LS3 as opposed to a LS2 for each decile are also reported.

was between digital dermatitis and toe necrosis, followed by the correlation between overgrown claws and corkscrew claws, between interdigital hyperplasia and digital dermatitis, and between sole ulcers and digital dermatitis.

We found a correlation between having the infectious lesion digital dermatitis (r = 0.31) and heel erosion (r = 0.44), respectively, on 1 back hoof, and having the same lesion on the opposing back hoof. Similarly, weak correlations we detected between having the noninfectious lesions white line separation (r = 0.28), sole hemorrhages (r = 0.35), foreign bodies (r = 0.26), corkscrew claws (r = 0.29), and overgrown claws (r = 0.34) on 1 back hoof and having the same lesion on the opposing back hoof.

Risk Factors for Digital Dermatitis at Herd Level

Eleven predictors were selected in the final Enet and mBIC models (Table 4). Of these, 6 of the same predictors occurred in both model types, indicating that these are robust risk factors for digital dermatitis in lame cows. Three predictors were associated with an increased risk of digital dermatitis and 3 were associated with a decreased risk.

Cow track characteristics were risk factors for digital dermatitis. An increase in the proportion of cow tracks which were narrow (based on herd size; DAFM, 2021), and an increase in the proportion, which had small verges ($\leq$0.5 m) at 50 m after the collecting yard, were associated with reduced risk of digital dermatitis. An

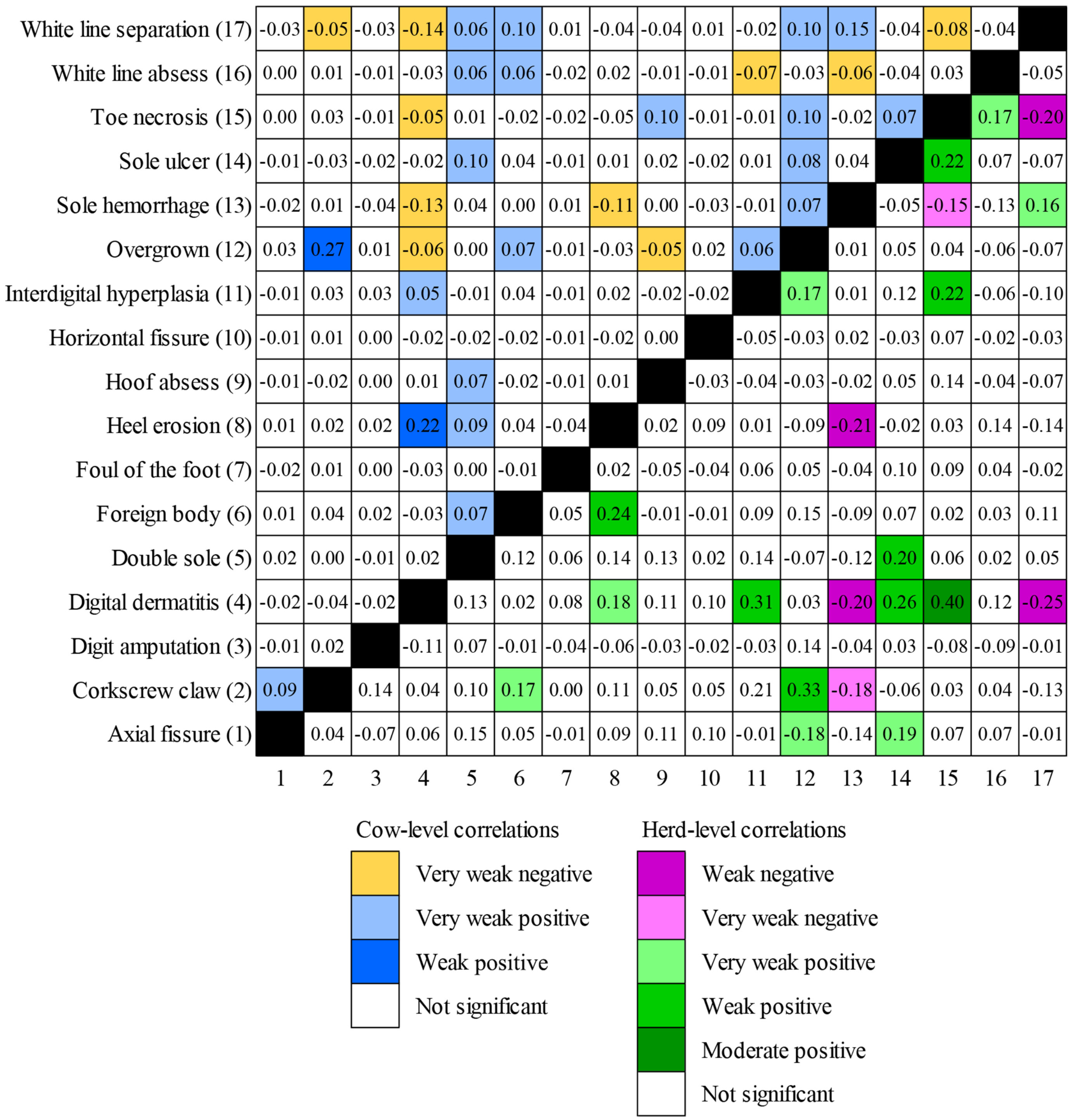

Figure 2. Correlation coefficient between lesions at cow level (binary scores; phi coefficient) and herd level (lesion prevalence; Spearman's coefficient) for lame cows in spring-calving, partly housed, pasture-based herds. Correlations between lesions with $P < 0.05$ are colored; white indicates that the correlation between lesions was not significant ($P \geq 0.05$). The color code enables visualization of correlation strength and direction: very weak (r = 0.01–0.19), weak (r = 0.20–0.39), and moderate (r = 0.40–0.59). Numbers on the x-axis refer to the lesions on the y-axis. Scores from both the grazing period (98 farms; April 2019–September 2019) and the housing period (74 farms; October 2019–February 2020) were used in the analysis.

Table 4. Risk factors for digital dermatitis at herd-level for lame cows in 98 spring-calving, partly housed, pasture-based herds during the grazing period (Apr. 2019–Sep. 2019), and in 74 of these herds during the housing period (Oct. 2019–Feb. 2020), using triangulation of elastic net regression (Enet), and logistic regression using modified Bayesian information criterion (mBIC)[1]

Predictor	Reference category (categorical predictors)	Mean standardized coefficient (lower 95% CI; upper 95% CI)		Odds ratio[2]		Stability rank		Bootstrap *P*-value	
		Enet	mBIC	Enet	mBIC	Enet	mBIC	Enet	mBIC
No cases of digital dermatitis, during the current lactation according to the farmer	>0% and ≤5% herd had digital dermatitis, during the current lactation according to the farmer	−1.851 (−4.509; −0.518)	−5.026 (−121.198; −2.804)	0.16	0.01	1	1	0.000	0.000
>5% herd had digital dermatitis, during the current lactation according to the farmer	>0% and ≤5% herd had digital dermatitis, during the current lactation according to the farmer	1.360 (0.167; 3.959)	4.810 (2.656; 183.145)	3.90	122.68	5	3	0.000	0.000
The proportion of cow tracks with a "medium" number of stones[3]		0.674 (0.091; 1.597)	1.528 (0.867; 47.683)	1.26	1.68	3	5	0.000	0.000
Proportion of small verges (≤0.5 m) at 50 m following the collecting yard		−0.483 (−1.374; −0.036)	−1.776 (−91.473; −1.079)	0.85	0.56	7	4	0.000	0.000
Lameness is considered a problem by the farmer	Lameness is not considered a problem by the farmer	0.877 (0.070; 2.573)	2.998 (1.835; 280.685)	2.40	20.04	6	7	0.000	0.000
Proportion of cow tracks that were narrow at 50 m following the collecting yard[4]		−0.609 (−1.501; −0.061)	−1.547 (−36.341; −0.909)	0.83	0.61	4	11	0.000	0.000

[1]Results are ordered by mean stability rank; the binary outcome is "digital dermatitis presence" (0 = digital dermatitis not recorded in the herd, 1 = digital dermatitis recorded in the herd).

[2]Odds ratios were calculated from unstandardized means; a unit change of 0.1 was used for continuous predictor.

[3]Nine to 17 quadrat squares out of 25 contain stones.

[4]Based on herd size (DAFM, 2021).

increase in the proportion of cow tracks with a "medium" number of stones (9 to 17 quadrat squares out of 25 contain stones; for method see Browne et al., 2022a) was associated with increased risk of digital dermatitis.

The recorded presence of digital dermatitis was also associated with farmer perception of digital dermatitis and lameness in the herd. Farms where more than 5% of the herd had digital dermatitis in the last year, according to the farmer, had lower odds of having digital dermatitis (compared with a herd >0 and ≤5%). However, where there were no cases of digital dermatitis in the last year, according to the farmer, the odds of digital dermatitis decreased (compared with a herd >0 and ≤5%). Farmers who considered their herd to have a lameness problem had higher odds of having digital dermatitis (compared with those that did not consider lameness to be a problem).

DISCUSSION

This large-scale study documents in detail hoof lesion types and relationships between lesions, compares lesion type with LS, and determines risks for digital dermatitis in lame cows, within an extensive partly housed, pasture-based dairy system.

Lesion Prevalence

Hoof lesions are the most common cause of lameness in dairy cows, so it is unsurprising that over 98% of lame cows examined in the current study had a minimum of 1 lesion on at least 1 hoof. However, only approximately 30% of lame cows were shown to have an alarm lesion present, which are always associated with pain (Kofler et al., 2022). It must also be noted that non-alarm lesions can still be painful and of concern, and should therefore not be ignored. Additionally, lameness may be caused by painful disorders located in the proximal limb. An average of 5.5 lesions were recorded per lame cow during the grazing period and 4.9 during the housing period, which is slightly higher than 3.4 lesions per lame cow reported previously in a similar partly housed, pasture-based system (Somers and O'Grady, 2015). Lame cows had an average of 3 different lesion types present, which indicates that a combination of lesions may have been responsible for lameness in individual cows, or that lameness is being caused by 1 lesion and that other lesions were observed but were not causing pain. Previous studies have reported that not all lesions will lead to lameness (Manske et al., 2002). In the present study, 1.6% of lame cows during grazing and 1.7% of lame cows during housing had no lesions present, demonstrating that a small number of lameness cases may be due to injury in places other than the hoof, that hoof problems may cause lameness without visible signs, or that lameness scoring may result in false positives.

Both the presence of a foreign body within the hoof sole (most commonly stones) and claw overgrowth in lame dairy cows were significantly more common during grazing, compared with housing. Penetration by a foreign body is likely more common during grazing due to cows stepping on stones when walking on tracks between the paddocks and the milking parlor, whereas in a housed environment, the presence of stones is less common. Overgrowth is caused when the claw growth rate is greater than the wear rate. Hahn et al. (1986) stated that both wear and growth rates where highest when cows where housed, compared with cows at pasture. Telezhenko et al. (2009) also reported that cattle housed on more abrasive surfaces have shown both increased growth rate and wear rate of the hoof, but also an overall lower net growth compared with cattle on less abrasive surfaces. Abrasive surfaces may also result in thin soles. Similarly, Chapinal et al. (2010) reported that net growth rate for cows with nighttime pasture access was also higher compared with fully housed cows. The higher prevalence of overgrown claws during the grazing period compared with the housing period in this study may suggest that net growth was highest when cows were at pasture.

In agreement with other partly housed, pasture-based studies, the most common hoof lesions in lame cows were sole hemorrhages and white line separation; however, the prevalence of these lesions were generally higher than in previous studies (Navarro et al., 2013; Somers and O'Grady, 2015). Somers and O'Grady (2015) reported that white line separation (with or without abscess) and sole hemorrhages were the most common lesion types in partly housed, pasture-based lame cows, with a prevalence of 52 and 63%, respectively. Somers and O'Grady (2015) also reported lower levels of overgrown claws (>80 mm) compared with the current study. The lower prevalence may be due to the 10 herds in the study participating in a herd-health program, which included lameness monitoring. In Swiss dairy herds (Becker et al., 2014), where cows gain frequent pasture access, cow-level prevalence of widened white line (81%) was similar to the prevalence of white line separation reported in the current study. The prevalence of white line disease (septic lesion) reported by Becker et al. (2014) was less than 5%, which is also similar to the prevalence of white line abscess reported in the current study.

Sole hemorrhages, white line separation, and overgrown claws were also found to affect the highest number of herds. It is proposed that walking on uneven and stony surfaces is a risk for white line disease (Archer et al., 2010); Chesterton et al. (1989) reported that poor maintenance of cow tracks was a risk for lameness. Cows in this study walked an average of approximately 2,000 m/d in total between milking and pasture, possibly explaining the high number of farms affected during grazing. This emphasizes how an important part of lameness prevention is maintaining cow tracks and ensuring they are stone free. Browne et al. (2022a) also reported that a high number of stones in paddock gateways was a risk for lameness. It is plausible that the high prevalence of white line separation observed during housing may be due to the time delay between injury to the hoof during the grazing period and manifestation of the lesion during the housing period; in fact, lesions can take at least 6 wk to become visible on the hoof sole (Ossent and Lischer, 1998). Long periods of time standing on concrete is also thought to pose a risk for claw horn lesions such as white line disease and sole hemorrhages (Bicalho and Oikonomou, 2013). In this study, 56% of dairy farms had less than 1.1 cubicles per cow in all pens, potentially leading to decreased lying time and increased standing time. Overstocking during housing has been reported to decrease time and thus increase lesion severity (Leonard et al., 1996). Somers and O'Grady (2015) reported similar findings in partly housed, pasture-based dairy cows: white line disease (separation with or without abscess) and sole hemorrhages were present on all farms visited. Based on the current study, farmers may benefit from routine trimming the entire herd to prevent overgrown claws. Routine trimming can also be a useful method for treating all undiagnosed lesions and for preventing hoof lesions forming, further reducing lameness incidence (Sadiq et al., 2020, 2021).

It is well known that infectious lesions are less common than noninfectious lesions in pasture-based systems (Somers and O'Grady, 2015). The cow-level prevalence of digital dermatitis in the current study was 12.4% during grazing and 13.2% during housing, which is comparably lower than Somers and O'Grady (2015), who reported a prevalence of 28% in lame partly housed, pasture-based dairy cows. The difference may be due to management differing on the 10 farms examined by Somers and O'Grady (2015), and due to hoof scoring only taking place over a 2-mo period. Similar to Somers and O'Grady (2015), Becker et al. (2014) reported a cow-level digital dermatitis prevalence of 29% in Swiss dairy cows within a similar system type. In contrast, infectious lesions are generally more common in housed systems (Cramer et al., 2008; Solano et al., 2016). Solano et al. (2016) reported that digital dermatitis was the most common lesion in housed Canadian cattle, with a cow-level prevalence of 15%. The prevalence reported by Solano et al. (2016) is similar to the prevalence found in the current study; however, their study collected data from all cows at routine trimming, as opposed to lame cows only, which suggests that digital dermatitis in partly housed, pasture-based herds was lower in comparison. Digital dermatitis was only recorded in 35% of herds in the current study; however, in housed systems, up to 94% of herds have digital dermatitis present (Solano et al., 2016). This emphasizes the extent of the problem in housed environments, where the buildup of manure is more common.

Lesions Associated with a Higher Lameness Score

Foul of the foot, white line abscess, sole ulcers, toe necrosis, interdigital hyperplasia, and digit amputation were associated with the highest odds of a cow being LS3 (severely impaired mobility) compared with being LS2 (impaired mobility), indicating that these lesions are associated with higher pain levels than other lesions identified. Previous publications have also identified lesions that elicit more severe pain (Tadich et al., 2010; Somers and O'Grady, 2015). Similar to the current study, Somers and O'Grady (2015) concluded that ulcers and white line disease led to higher pain in lame partly housed, pasture-based dairy cows; however, their study did not separate white line separation with white line abscess as we did is our study. Somers and O'Grady (2015) also reported that axial fissures and vertical fissures resulted in a higher LS. Farmers need to effectively detect and treat mild lesions early to prevent more severe lesions occurring (Groenevelt et al., 2014). For example, treating sole hemorrhages may prevent the more painful sole ulcer occurring, and avert the need for digit amputation. The use of nonsteroidal anti-inflammatory drugs, in conjunction with a trim and block, can contribute to higher cure rates and to improved animal welfare through reduced pain (Thomas et al., 2015). Ranjbar et al. (2021) reported that, in grazing cows that walked over 2,000 m/d, higher density blocks should be used to increase block longevity. In addition, farmers could consider focusing preventative efforts on the lesions found to be most painful.

Digit amputation is often used to treat deep infections within the hoof when less invasive treatment methods are unsuccessful. However, the success rate of digit amputation is relatively low; for example, Bicalho et al. (2006) reported that 45% of cows were culled within 60 d postsurgery. In addition, Starke et al. (2007) and Devaux et al. (2017) reported the mean survival rate postamputation to be 13.5 and 15 mo, respectively. The most common reason for culling following amputation is lameness (Starke et al., 2007). Effective prevention and treatment of lesions on the remaining claw is essential for increasing life span postamputation (Heppelmann et al., 2009). Most importantly, preventing severe lesions is key for eliminating the need for digit amputation in the first instance.

Relationship Between Lesions

In the present study, the strongest correlation between lesions at herd level was between toe necrosis and digital dermatitis in lame cows. Similarly, a previous study reported that digital dermatitis treponeme DNA was present in 84% of tissue samples taken from cows with nonhealing toe necrosis (Evans et al., 2011). In contrast, no DNA was present in healthy tissue samples from cows without toe necrosis (Evans et al., 2011). It has also been proposed that the reduced bone density and proliferation of the laminar corium in cows with toe necrosis may be due to the presence of the digital dermatitis treponemes (Blowey et al., 2013). It is generally believed that damaged necrotic tissue allows for digital dermatitis treponemes to enter the hoof, thus leading to the lesion becoming nonhealing (Kofler, 2017). However, it has also been theorized that digital dermatitis treponemes may cause damage at the coronary band, leading to the hoof wall splitting and allowing digital dermatitis treponemes to enter, predisposing to toe necrosis (Atkinson and Wright, 2013). The correlations found in this study do not enable a cause and effect relationship to be established. In either case, preventing digital dermatitis may prevent toe necrosis (Atkinson and Wright, 2013), or preventing claw horn lesions in general may prevent severe nonhealing cases of all digital dermatitis-associated lesions (Kofler, 2017).

This study also demonstrated an association between digital dermatitis and sole ulcers in lame cows. Similar to nonhealing toe necrosis, digital dermatitis treponeme DNA has previously been present in nonhealing sole ulcer tissue samples (Evans et al., 2011). However, unlike toe necrosis, it has not been speculated that digital dermatitis treponemes in sole ulcers cause changes in pedal bone pathology (Blowey et al., 2013), or that digital dermatitis may predispose to sole ulcers (Atkinson and Wright, 2013). As previously reported, digital dermatitis was also found to be associated with the infectious lesions, interdigital hyperplasia, and heel erosion (Manske et al., 2002; Holzhauer et al., 2006). Evans et al. (2011) demonstrated that digital dermatitis treponemes were not present in heel erosion tissue samples, indicating that the bacteria causing these lesions differ. It is speculated that the relationship between these infectious lesions are likely due to the bacteria associated with these lesions, all thriving in similar unhygienic environmental conditions.

Risk Factors for Digital Dermatitis at Herd Level

On farms where digital dermatitis was present in the herd within the last year, according to the farmer, there was an increased odds of digital dermatitis. Similarly, on farms where farmers stated they had no digital dermatitis in the herd, there was a reduced risk. This is unsurprising; however, it demonstrates that farmers were aware of the presence of digital dermatitis in their herd. The odds of digital dermatitis was also increased when the farmer considered themselves to have a lameness problem in their herd, which is indicative of the farmers' ability to perceive that digital dermatitis was a problem in their herd. However, despite 44% of farmers reporting that digital dermatitis was present in their herd in the last year, only 31% of farmers footbathed more than 12 times per year in this study (Browne et al., 2022b). Farmers should be encouraged to talk to their vet regarding optimal footbathing protocols and digital dermatitis treatment to reduce digital dermatitis in their herd.

Various cow track features influenced the risk of digital dermatitis. A higher proportion of cow tracks with small verges (<0.5 m), at 50 m following the collecting yard, reduced the odds of digital dermatitis. A small verge prevents cows from walking on the grass margin as opposed to the track, whereas large verges may result in cows walking and standing on the grass margins (Tuohy et al., 2017), creating muddy conditions that lead to increased digital dermatitis risk. A higher proportion of narrow cow tracks at the first 50 m following the collecting yard also reduced the risk of digital dermatitis. On farms where the majority of cow tracks were narrow, the most common surface type was subsoil within the first 50 m. Contrastingly, on farms where the majority of cow tracks were wide, concrete was the most common surface type within the first 50 m. It is possible that concrete allowed for manure to pool, thus increasing the risk of digital dermatitis (Blowey, 2006). A second theory is that farms with narrow cow tracks near the collecting yard may have been more likely to maintain and clean the area, preventing the buildup of manure. An increase in the proportion of cow tracks with a "medium" number of stones increased the risk of digital dermatitis. This may be linked to stones causing skin abrasions, allowing digital dermatitis treponemes to enter (Krull et al., 2016).

Some of the mBIC coefficients reported in this study are relatively large. Coefficients based on mBIC are generally somewhat inflated, whereas Enet coefficients are generally somewhat deflated (Lima et al., 2021). The range between these estimates is, therefore, a plausible range within which the true value is likely to lie. If conventional regression was used for this analysis, it is likely that these coefficients would be further inflated, and that more false-positive results would have been reported. In addition, the mBIC coefficients are largely inflated for risk factors that would be expect to have a strong relationship (e.g., proportion of herd with digital dermatitis according to the farmer); therefore, accurately quantifying the size of the relationship is of less interest.

Study Limitations

Farmers in this study had the choice of participation; therefore, some degree of selection bias may have occurred. Farmers that were more aware of lameness and hoof care may have been more willing to participate; however, those with a lameness problem may have also signed up to the study to get their lame cows identified and treated. Additional bias may have also occurred through subjective diagnosis of hoof lesions by different observers. To mitigate this effect, all observers were trained in lesion identification and a guide was created with photographs to refer to throughout the study. Ideally, both the hooves of non-lame cows as well as lame cows would have been examined; however, as resources and time were limiting factors in conducting this labor-intensive study, it was only viable to hoof score a maximum of 20 cows per farm. Therefore, it was decided that the most valuable information would be obtained by examining the hooves of a larger number of only lame cows per herd. The correlation between lesion types is an indication of a relationship; however, this does not imply causation. Similarly, in the risk factor analysis for digital dermatitis, the cause and effect cannot be depicted. Herd-level risk factor analysis was only carried out for digital dermatitis. This is because digital dermatitis is an infectious disease and spreads between cows, and it is generally present in some herds and absent in other herds. In contrast, the most prevalent noninfectious lesions were present on a very high proportion of farms, making herd-level risk factor analysis not possible.

CONCLUSIONS

This study identified that the noninfectious lesions white line separation, sole hemorrhages, and overgrown claws were the most prevalent lesions at both the cow and herd level. A low prevalence of infectious lesions was identified. All lesion types had a similar prevalence between grazing and housing, with the exception of foreign bodies within the hoof sole and overgrown claws, which had a higher prevalence during grazing. Cows had higher odds of being severely lame, compared with mildly lame, if they had an amputated claw, foul of the foot, white line abscess, sole ulcer, or toe necrosis. Toe necrosis and digital dermatitis had the strongest correlation of all lesion types, followed by overgrown claws and corkscrew claws, and interdigital dermatitis and digital dermatitis, all at herd level. The farmers' perception of digital dermatitis and lameness in the herd, as well as cow track characteristics, were identified as risk factors for digital dermatitis. Identifying the main causes of lameness in a partly housed, pasture-based system helps provide a focus for treating and preventing these lesion types.

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