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Risk factors associated with hair loss, ulceration, and swelling at the hock in freestall-housed UK dairy herds

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ABSTRACT

The objective of this study was to identify the risk factors associated with 3 presentations of hock lesions (hair loss, ulceration, and swelling) in freestall-housed lactating cattle. By independent identification and scoring of, and analysis of the factors associated with, hair loss, ulceration, and swelling, the aim was to identify whether risk factors were common to all 3, or differed among the presentations. A cross-sectional study was conducted on 76 herds in the UK during the winter housing period of 2007 to 2008, with a total of 3,691 cows examined for hock lesions. A randomly selected sample of approximately 50 cows in each herd were scored for body condition, lameness, cleanliness, rising behavior, and lesions at the hocks. For all cows, hair loss, ulceration, and swelling were scored separately on 4-point scales, with both left and right hocks scored. Based on a review of the literature, potential risk factors were identified and measured, collected from milk-recording data, or obtained through interviews with the farmers. Risk factors associated with hocks lesions in cattle were examined using data from the 2,982 cows housed in the 63 freestall-housed herds visited. Risk factors for each of the 3 lesion presentations were considered separately in multilevel logistic regression models, with moderate or severe hair loss, any degree of ulceration, and moderate or severe swelling as the outcome variables. Thirty risk factors were identified, none of which were common to all 3 lesion presentations. Five risk factors (locomotion score, number of days of winter housing, mean milk yield, freestall base material, and herd size) were common to both hair loss and ulceration. The stall bedding material was a common risk factor for both hair loss and swelling. A further 8, 5, and 11 risk factors were unique to hair loss, ulceration, and swelling, respectively. The existence of several differential risk factors between the 2 lesion presentations suggests that ulceration may not always be a direct extension of hair loss, as has been implied in previous scoring systems. Of the 12 risk factors associated with swelling, only 1 was common to another lesion presentation, which suggests that swelling may have a different etiology than hair loss and ulceration. The variables associated with the lesions indicate the importance of factors that affect the lying and rising behavior of the animal, including freestall structure and design, and the lying surface.

Key words: hock lesion, dairy cow, housing, welfare

INTRODUCTION

Hock lesions are prevalent in housed dairy cattle across the UK (Rutherford et al., 2008), Europe (Kielland et al., 2009), and North America (Fulwider et al., 2007), and have been associated with a large number of cow- (Regula et al., 2004; Haskell et al., 2006) and herd-level risk factors (Fulwider et al., 2007; Kielland et al., 2009). Positive correlations have been demonstrated, most notably, among the prevalence and severity of hock lesions and levels of lameness within a herd (Haskell et al., 2006; Fulwider et al., 2007; Kielland et al., 2009), with the lesions also linked to the presence of other injuries and signs of ill health in dairy cattle (Regula et al., 2004; Fulwider et al., 2007).

In spite of the body of knowledge associated with hock lesions and an increasing awareness of prevalence, a commonly agreed scoring system for the condition does not exist. Currently, the term hock lesion is used to describe a wide range of presentations, including incidents of damaged and missing hair, abraded or broken skin, scabs, and swelling (Weary and Taszkun, 2000; Rutherford et al., 2008). Implicit in most scoring systems is the linear progression of lesions from hair loss, through to wounds and scabs, often terminating with swelling as one of the most severe representations (Fulwider et al., 2007). Subjective assessments of lesion severity and hence biological significance have been made, with both wounds and swelling commonly considered to be more severe than areas of hair loss alone (Barberg et al., 2007; Lombard et al., 2010). However, a lack of accurate characterizations of lesion develop-

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ment and progression, such as longitudinal data, exists to support these classification assumptions. Although some longitudinal work assessing hock lesions has been conducted, including that of Livesey et al. (2002) and Norring et al. (2008), large-scale studies are lacking.

Correlations among the different lesion presentations have been the subject of very little work, although they have been explored by Whay et al. (2003). Most previous studies have assigned a single score or grade either to a lesion, area, or limb according to the overall lesion presentation or a subjective assessment of lesion severity. Consequently, in previous publications, risk factors associated with hock lesions have been analyzed against the presence of a lesion (versus the absence of a lesion; Rutherford et al., 2008; Kielland et al., 2009) or against whichever of the lesion presentations was judged to be the most severe (Lombard et al., 2010).

The objective of the work described here was to identify the risk factors associated with 3 presentations of hock lesions (hair loss, ulceration, and swelling) in freestall-housed lactating cattle in a sample of dairy herds in the Midlands area of the United Kingdom. By independent identification and scoring of hair loss, ulceration, and swelling, as well as the analysis of the factors associated with each, the aim was to identify whether risk factors were common to, or differed among, the 3 presentations.

MATERIALS AND METHODS

Study Population

Seventy-seven dairy herds from the Midlands region of the United Kingdom were recruited through 5 local veterinary practices. Criteria for inclusion in the study were current enrollment in a milk-recording scheme and the ability to identify and match cows to their milk records. Farmers were contacted chronologically as lists were obtained from the individual veterinary practices.

Farm Visits

Each farm was visited once between November 2007 and April 2008. Minimum periods of 4 wk from the start of the winter housing season, or 3 mo after alterations to the indoor housing, to the date of the visit were specified. All visits were conducted by one observer (S. Potterton). The study methodology was reviewed and approved by the University of Nottingham School of Veterinary Medicine and Science Ethical Review Committee before commencement of farm visits.

Cow Selection and Assessment

From each herd, a sample of approximately 50 cows was assessed. Cows were selected randomly across all lactating groups, excluding groups of sick or freshly calved animals. No dry cows, or animals housed outside of the milking herd were examined. Random selection was achieved by blind selection of marbles from a pocket. Several identically sized marbles of 2 different colors were placed in a pocket, with 1 color representing inclusion of the cow in the sample and the other non-inclusion. The ratio of the 2 different colored marbles represented the proportion of cows required to be sampled in the herd to achieve a total of approximately 50 individual assessments. Each cow in the group was considered individually and a marble drawn from the pocket. The color of the marble drawn determined whether or not the cow was included in the sample. Animals were then physically marked or recorded in order that they were not selected again. Selection finished when all cows in the milking herd had been through the selection process.

Selected cows were scored for body condition, lameness, cleanliness, rising behavior, and lesions at the hocks. Assessments were conducted within the feed or housing area, with animals remaining unrestrained. Body condition score was assigned visually on a scale from 1 to 5, according to standard methodology (with inclusion of half points; Wildman et al., 1982). A locomotion score was assigned according to the 4-point scale described by Whay et al. (2003): sound (0), abnormal locomotion (1), lame (2), and severely lame (3). The scores were based on descriptors including arching of the back, stride length and rhythm, and weight bearing. Seven separate areas of the body were assigned a cleanliness score on a scale of 0 to 4: the tail, left and right flanks, and lower (midpoint of the tibia to the midpoint of the metatarsus) and upper hind limbs (hip down to the midpoint of the tibia) on the left and right-hand sides. The descriptors were similar to those described by Whay et al. (2003), with cows having no soiling (0), or mild (1), medium (2), or severe (3) amounts of soiling, but with an additional score to include animals displaying extensive areas of caked soiling (4). Cows lying down when approached were encouraged to rise using steadily increasing verbal and physical encouragement. The time taken to rise, from first rising movement until all 4 feet were placed flat on the ground, was measured, and evidence of the following behavior was recorded: intention movements (where an animal appears to be seeking a lunging space, but does not proceed to lunge); sideways lunge movements; repeated attempts at rising; a pause of greater than 2 s while the animal is resting on its knees with its back legs extended; slips during rising; dog-sitting; and contact with the freestall fittings.

Hair loss and ulceration at the hocks were each scored separately on 4-point scales, as employed by Whay et al. (2003). Both left and right hocks were scored on each cow. Hair loss at the hock was scored according to the following criteria: hair undisturbed with no loss (0); area of hair loss less than approximately 2 cm in diameter (1/mild); area of hair loss between approximately 2 and 2.5 cm in diameter (2/moderate); and area of hair loss greater than approximately 2.5 cm in diameter (3/severe). Ulceration at the hock was scored according to the following criteria: no ulceration (0); area of ulceration less than approximately 2 cm in diameter (1/mild); area of ulceration between approximately 2 and 2.5 cm in diameter (2/moderate); and area of ulceration greater than approximately 2.5 cm in diameter (3/severe). Swelling of the hock was scored for each hind limb while standing directly behind the animal. Scores were assigned according to the 4-point scale used by Whay et al. (2003): no swelling (0); hock is thicker than normal (1); hock is obviously swollen (2); and hock is extensively swollen (3). However, no scores of 0 were recorded for swelling.

Environmental Assessment

The environment for each group of lactating cows was assessed. Measurements were taken of feed space, passageways, and loafing areas. The surface of the passageways and standing areas were also scored according to the nature and the condition of the surface. The total number of freestalls available to each housing group was counted.

The dimensions of the freestalls on each farm were measured and the nature of the base and bedding material recorded. Cows were almost always housed on a freestall base on top of which bedding was added; the base and the bedding materials were recorded and considered separately in the analyses. Stall measurements were taken to include 12 elements: total length; distance from the curb to the brisket positioner; length of any mat or mattress; width; curb height; width of curb left exposed when a mat or mattress was present; height of brisket positioner; distance from the neck rail to the curb (on the diagonal); height of neck rail; height of the lowest side rail at both the rear (40 cm in from rear of bed) and front of the freestall (at point of brisket positioner); and distance between lower and upper side rails at the front end of the freestall (at point of brisket positioner). Sixteen randomly selected freestalls were used to determine the mean depth or volume of bedding and were also assessed for the presence of foreign objects (greater than 2 cm in diameter). Each cubicle was assigned a number. Numbers were assigned starting at 1, with the cubicle closest to the entrance to the yard used by the observer, and by continuing in a systematic method through the yard. Sixteen random numbers were then generated using the random number function in Microsoft Excel 2003 (Microsoft Corp., Redmond, WA). The correspondingly numbered cubicles were assessed. Sixteen cubicles were selected based on an initial power calculation with the following assumptions for bedding depth and volume. To estimate the average depth (or volume) of bedding on a particular farm to within 0.75 cm (or 0.75 L, which the authors deemed to be an acceptable accuracy) and assuming a standard deviation of depth (or volume) of bedding within a farm to be 1 cm (or 1 L), this meant that 16 cubicles would be needed (assuming a power of 0.8 and an α of 0.05). Depth was determined for deep-bedded freestalls (e.g., straw, sand, or deep sawdust, at 3 separate points, each 40 cm in from the rear of the bed; at the midpoint across the width of the freestall and then at 2 further points, one 40 cm on either side of the midpoint). The volume was determined for small quantities of bedding (e.g., a shallow layer of sawdust, by collecting and measuring all of the bedding present within a sampling frame (80 × 80 cm) placed centrally at the rear of the bed. On farms having more than 1 type of freestall, 16 stalls of each type were considered and assessed independently.

For the freestalls within each housing group, assessments were made of the number of each with the following: broken side, neck and head rails; incorrectly positioned mats or mattresses (greater than 15° skew); nonparallel side rails; side lunge space available on just one side; interrupted forward lunge or bob space (interrupted lunge space was defined as any obstructions 1 m in front of the brisket positioner, above the height of the brisket positioner, and interrupted bob space 1 m in front of the brisket positioner, below the height of the positioner); and the number of freestalls directly facing a wall.

Farmer Interviews

A researcher-mediated questionnaire was designed and used to collect information on the herd, housing and associated management practices. The farm owner(s) was identified for interview unless they had little or no involvement in the daily management of the herd, in which case the herd manager or head stockperson was interviewed.

Milk Records

Milk recording data were downloaded and imported into herd management software (InterHerd, version 2.11.0; InterAgri, Reading, UK), and from this, data tables for individual herds were created in Microsoft Access 2003 (Microsoft Corp.).

Data Handling

The collected data were entered into a relational database (Microsoft Access 2003; Microsoft Corp.) and audited. The data were exported into Microsoft Excel 2003 (Microsoft Corp.), Minitab (version 15.1, Minitab Inc., Philadelphia, PA), and MLwiN (version 2.20; Centre for Multilevel Modeling, University of Bristol, UK) for analysis. Several summary parameters were calculated from the raw data. Total animal cleanliness score was calculated by summing the scores for the 7 individual body areas examined. Mean milk yield was calculated from each cow's 3 most recent monthly milk recordings within the current lactation. If an animal had been calved for less than 3 mo, then the mean milk yield was calculated from the number of available milk recordings for that lactation. The number of days of winter housing was calculated from the housing date given by the farmer; for zero-grazed herds, this was specified as 365 d.

Observations for each variable were categorized into between 2 and 5 groups, each containing approximately equal numbers of observations. The number of groups was partially dependent on the spread of the data, and the biological significance of observations was also taken into account during this process. For the variable freestall base material, the defined categories were mat, mattress, and other (waterbed, earth, manure, clay, hardcore, limestone, woodchip, fiber board, concrete and earth, concrete and hardcore, hardcore and tires, earth and limestone, and stone and manure). For the variable floor type of freestall yard, the categories were smooth concrete, grooved concrete, textured concrete, textured and grooved concrete, and other (any other combination of smooth, textured, grooved, and slatted concrete).

Statistical Analysis

Of the 77 farms visited, 1 was excluded from the data set because the cows in the herd could not be readily identified by the observer. On 13 of the remaining 76 farms, the milking herd was housed exclusively on straw yards, and on 7, both straw yards and freestalls were used to house milking animals. All cows housed in straw yards were excluded from the analyses because the overall prevalence of lesions within these systems was much lower than in freestall-housed herds (54.6 vs. 87.4% of cows with hair loss lesions; 9.3 vs. 18.1% with ulceration lesions; 7.6 vs. 25.3% with moderate or severe swellings). In herds where cows had access to multiple stall types, the stall data were excluded from the analyses.

The hair loss, ulceration, and swelling scores for the most severely affected limb were selected from each cow for analysis purposes. The analysis was conducted in MLwiN (Centre for Multilevel Modeling, University of Bristol) using conventional multilevel models. In the first set of models, hair loss was the outcome variable of interest with a binary indicator of hocks with no or mild hair loss (scores 0 and 1) and with moderate or severe hair loss (scores 2 and 3). In the second set of models, ulceration was used as the outcome variable of interest, with a binary indicator of hocks with (scores 1 to 3) and without ulceration (score 0). In the third set of models, swelling was selected as the outcome variable of interest with a binary indicator of hocks with mild swelling (score 1) and with moderate or severe swelling (scores 2 and 3). The thresholds for consideration in the models were set according to the bottom category of each lesion presentation scored, except with hair loss, where the majority of cows had at least mild hair loss at the hock. The data were hierarchical, consisting of hair loss, ulceration, or swelling associated with each hock of a cow within a farm. Models were specified so that correlations within the data (hocks within cows within farms) were accounted for appropriately. Model specifications were

$$\text{Outcome}_{ijk} \sim \text{Bernoulli (probability} = \pi_{ijk})$$

$$\text{Logit } (\pi_{ijk}) = \alpha + \beta_1 X_{ijk} + \beta_2 X_{jk} + \beta_3 X_k + v_k + u_j,\ v_k \sim N(0,\Omega_v),\ u_j \sim N(0,\Omega_u),$$

where the outcome was either moderate or severe hair loss; mild, moderate, or severe ulceration; or moderate or severe swelling. The subscripts i, j, and k denote the ith hock, the jth cow, and the kth farm, respectively; α is the regression intercept; X_{ijk} is the vector of covariates at the hock level; β_1 is the coefficient for covariate X_{ijk}; X_{jk} is the vector of cow-level covariates; β_2 is the coefficient for covariate X_{jk}; X_k is the vector of farm-level covariates; β_3 is the coefficient for covariate X_k; v_k is the random effect to reflect residual variation among farms and was assumed to follow a normal distribution with mean = 0 and variance = Ω_v; and u_j is the random effect to reflect residual variation among cows and was assumed to follow a normal distribution with mean = 0 and variance = Ω_u.

Initially, for each set of models, 3 submodels were created for cow-level covariates (e.g., BCS and parity; model a); covariates associated with the lying environment of the cow (e.g., freestall type and depth of bedding; model b); and farm-level covariates (e.g., herd size and loafing area per cow; model c). Terms were added to the models individually, with all of the measured variables considered. Terms that demonstrated significance ($P < 0.05$) were retained in the model, whereas those that were nonsignificant (or became nonsignificant when a further term was added) were removed. When all terms had been tested in the model, terms that were initially nonsignificant in the model were re-tested. These terms were again added individually to the model and checked for significance when the model was re-run. The final model was obtained when all terms in the model demonstrated significance and those not retained had been discarded as nonsignificant.

When final models had been reached for each of models 1 to 3 for hair loss, ulceration, and swelling, final models (model 4) were created that included cow-level, lying environment, and farm-level covariates. Terms deemed significant in the 3 individual models were carried forward and tested in the final models. The final models were built up as described above for models 1 to 3. Odds ratios with 95% confidence intervals were calculated for all significant variables in the final models.

RESULTS

Herd Characteristics

After removing from the data set the 13 farms where the milking herd was housed exclusively on straw yards, 63 herds with freestall housing remained. These herds were visited between November 2007 and April 2008, with a total of 2,982 cows examined for hock lesions. The 63 herds were located in the Midlands region of the United Kingdom across 7 counties.

Mean herd size was 162 cows (range: 46 to 394), with a mean of 140 cows in milk (median: 125) at the time of the visit. Herds were predominantly Holstein-Friesian with 2 Jersey herds included within the sample. The mean number of freestall-housed cows assessed per herd was 47 (range: 27 to 60). The proportion of the total number of freestall-housed cows on each farm that was examined ranged from 15.5 to 100.0% (mean: 44.6%).

Fifty-six herds used freestall housing exclusively, and 7 used both straw yards and freestall housing. Details of freestall type and dimensions were recorded for 62 of the 63 herds using this housing system. Due to an unforeseen event, the visit to one of the herds ended abruptly, before the details of the freestalls could be collected. Forty-three of the herds using freestalls had a single combination of base type and bedding, 15 had 2 combinations, 3 herds had 3 combinations, and 1 herd encompassed 4 combinations.

Sample Characteristics

Sampled cows ranged between lactation number 1 and 11 [median: 2; interquartile range (**IQR**): 1 to 4], with a mean age of 5.1 yr (IQR: 3.4 to 6.3). Cows were, on average, 196 DIM (range: 2 to 979; IQR: 101 to 263) at the time of the visit. Mean milk yield at date of last milk recording was 26.9 kg, with a range of 2.6 to 59.9 kg (IQR: 19.5 to 33.6). For cows with a recorded breed, the majority were Holstein (n = 22), Friesian (n = 98), or Holstein-Friesian (n = 4,702), with Jersey (n = 190), Ayrshire (n = 80), Brown Swiss (n = 26), and other breeds (n = 10) represented.

Prevalence and Severity of Hair Loss, Ulceration, and Swelling at the Hock

Of the 5,652 hocks scored for hair loss, a total of 2,267 had moderate (25.6% of hocks scored) or severe (14.5% of hocks scored) hair loss (score 2 or 3). The median percentage of hocks per herd displaying hair loss (of any severity) was 91.7% (IQR: 83.5 to 95.7%; minimum: 39.6%; maximum: 100.0%; Figure 1). The median value for moderate to severe hair loss (score 2 or 3) was 44.7% (IQR: 20.6 to 56.9%; minimum: 1.1%; maximum: 92.6%). Of the 5,652 hocks scored for ulceration, 1,021 (18.1%) of these had some degree of ulceration. A total of 378 hocks (6.7% of hocks scored) had moderate ulceration (score 2) and 142 hocks (2.5% of hocks scored) had severe ulceration (score 3). The median percentage of hocks per herd displaying ulceration (of any severity) was 13.8% (IQR: 5.8 to 28.4%; minimum: 0.0%; maximum: 51.1%; Figure 2). Of the 5,877 hocks scored for swelling, none were score 0. A total of 1,489 had moderate (23.0% of hocks scored) or severe (2.3% of hocks scored) swelling (score 2 or 3). The median percentage of hocks per herd displaying swelling that was moderate or severe was 25.0% (IQR: 15.5 to 31.9%; minimum: 0.0%; maximum: 64.7%; Figure 3).

Risk Factors Associated with Hair Loss, Ulceration, and Swelling at the Hock

The risk factors that were associated with hair loss, ulceration, and swelling at the hock are outlined in Tables 1 to 3. None of the 30 identified risk factors were common to all 3 lesion presentations. Locomotion score, number of days of winter housing, mean milk yield, freestall base material, and herd size were common to both hair loss and ulceration. The stall bedding material was a common risk factor for both hair loss and swelling. Superscripts in Tables 1 to 3 indicate those risk factors that were common between the pairs of lesion presentations. However, the same categories of each risk factor were not always significant for each presentation (the details of which can be found in Tables 1 to 3). A further 8, 5, and 11 risk factors were unique to hair loss, ulceration, and swelling, respectively.

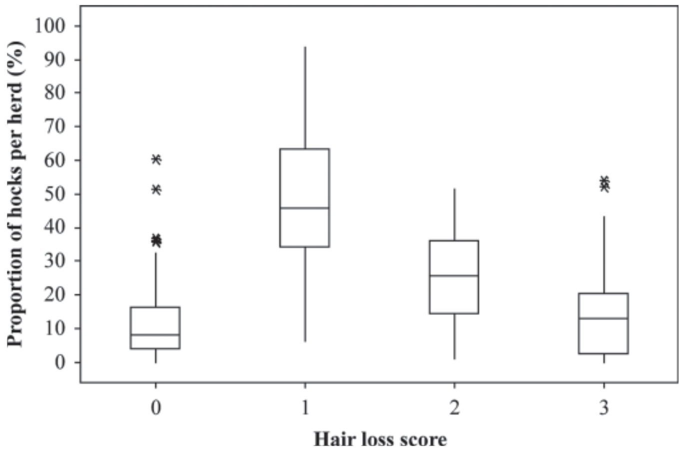

Figure 1. Proportion of hocks assigned each hair loss score in 63 herds.

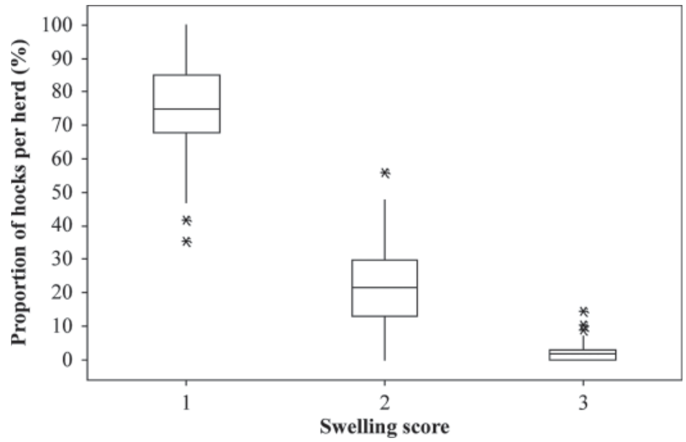

Figure 3. Proportion of hocks assigned each swelling score in 63 herds.

Locomotion score, number of days of winter housing, and the frequency of application of hygiene products to freestalls were all positively correlated with hair loss. Freestall base and bedding materials were a risk factor for hair loss, as were elements of the cubicle dimensions, and the age of mats and mattresses in the stalls. Other factors associated with hock hair loss were the mean milk yield, parity and breed of the cow, and the size of the herd.

Locomotion score, herd size and the proportion of freestalls with an interrupted bob zone were all positively correlated with ulceration at the hock. Total animal cleanliness score was negatively correlated with ulceration. Freestall base material and the floor type of freestall yards were risk factors for this lesion presentation, as were measurements of the condition of the stalls. Other factors associated with ulceration were the number of days of winter housing and the mean milk yield of the animal.

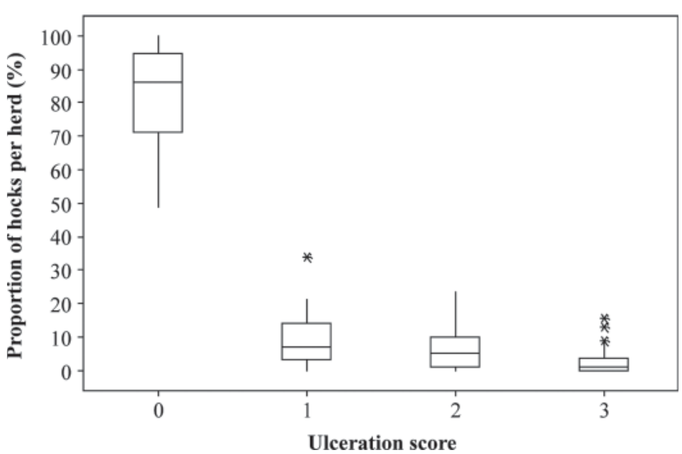

Figure 2. Proportion of hocks assigned each ulceration score in 63 herds.

Body condition score was negatively correlated with swelling at the hock, and DIM was positively correlated with this lesion presentation. Freestall bedding material, depth of bedding, and the quantity of hygiene products applied to stalls were risk factors for swelling. Other factors associated with the lesion presentation were the most recent milk yield of the animal and its rising behavior, as well as measures of stall condition and dimensions, and the stocking rate of the yard.

DISCUSSION

Previous hock-scoring methodologies have implied the linear development of lesions from hair loss through to wounds and scabs (Chaplin et al., 2000), often culminating with swelling (Fulwider et al., 2007). These methodologies have included subjective assessments of severity, with scabs and wounds commonly considered to be more severe than areas of hair loss alone (Barberg et al., 2007; Lombard et al., 2010). For the purposes of welfare assessments it may be valid to consider ulceration to be more severe then hair loss. However, the assumption surrounding the linear development of ulceration from hair loss is also inherent within studies examining risk factors. Risk factors have been modeled for the most severe lesion observed (Lombard et al., 2010) or the presence of any lesion (Kielland et al., 2009). In the current study, hair loss, ulceration, and swelling were identified and scored separately; no assumptions were made about lesion development or severity. Risk factors associated with the 3 lesion presentations were analyzed independently to further understanding of lesion etiology. Five risk factors were common between hair loss and ulceration and only 1

Table 1. Hair loss at the hock: results of the multilevel model for associated risk factors (moderate or severe hair loss = 1, no or mild hair loss = 0)

Model term	Coefficient	SE	Odds ratio	95% CI 2.5%	95% CI 97.5%	*P*-value
Locomotion[1]						
Score 0	Reference					
Score 1	0.03	0.11	1.03	0.83	1.28	NS
Score 2	0.32	0.09	1.38	1.15	1.64	*
Score 3	0.50	0.15	1.65	1.23	2.21	*
Days of winter housing[1]						
2 to 40 d	Reference					
41 to 76 d	0.31	0.17	1.36	0.98	1.90	NS
77 to 111 d	0.87	0.17	2.39	1.71	3.33	*
>112 d	0.92	0.18	2.51	1.76	3.57	*
Mean milk yield[1]						
2.4 to 20.7 kg	Reference					
20.8 to 26.9 kg	0.48	0.12	1.62	1.28	2.04	*
27.0 to 33.8 kg	0.41	0.12	1.51	1.19	1.91	*
33.9 to 58.1 kg	0.44	0.13	1.55	1.20	2.00	*
Parity						
1	Reference					
2	−0.20	0.11	0.82	0.66	1.02	NS
3 and 4	−0.26	0.11	0.77	0.62	0.96	*
5 to 11	0.31	0.12	1.36	1.08	1.72	*
Breed						
Includes Holstein	Reference					
Does not include Holstein	−0.74	0.22	0.48	0.31	0.73	*
Freestall base material[1]						
Mattress	Reference					
Concrete	−1.37	0.36	0.25	0.13	0.51	*
Mat	−0.27	0.27	0.76	0.45	1.30	NS
Other	−2.17	0.42	0.11	0.05	0.26	*
Freestall bedding material[2]						
Sawdust or wood shavings	Reference					
Sand	−1.66	0.39	0.19	0.09	0.41	*
Whole straw	−1.12	0.25	0.33	0.20	0.53	*
Chopped straw	−0.16	0.31	0.85	0.46	1.56	NS
Waste wood or paper	0.43	0.34	1.54	0.79	2.99	NS
Application of hygiene products to freestalls						
0.3 to 1.0 times/wk	Reference					
1.1 to 2.0 times/wk	0.51	0.25	1.67	1.02	2.72	*
2.1 to 3.5 times/wk	0.91	0.28	2.48	1.44	4.30	*
3.6 to 14.0 times/wk	1.22	0.31	3.39	1.84	6.22	*
Height of lowest side rail at front end of freestall						
0.09 to 0.23 m	Reference					
0.24 to 0.29 m	0.87	0.33	2.39	1.25	4.56	*
0.30 to 0.39 m	1.38	0.32	3.97	2.12	7.44	*
0.40 to 1.01 m	1.16	0.34	3.19	1.64	6.21	*
Time mats and mattresses have been in freestalls						
0 to 3 yr	Reference					
4 yr	0.48	0.28	1.62	0.93	2.80	NS
5 to 7 yr	−0.11	0.27	0.90	0.53	1.52	NS
8 to 16 yr	−0.70	0.29	0.50	0.28	0.88	*
Distance from neck rail to rear of the freestall						
1.88 to 1.98 m	Reference					
1.99 to 2.07 m	−0.71	0.41	0.49	0.22	1.10	NS
2.08 to 2.14 m	−2.00	0.38	0.14	0.06	0.29	*
2.15 to 2.37 m	−2.40	0.47	0.09	0.04	0.23	*
Height of neck rail						
0.91 to 1.10 m	Reference					
1.11 to 1.15 m	1.03	0.36	2.80	1.38	5.67	*
1.16 to 1.23 m	0.51	0.31	1.67	0.91	3.06	NS
1.24 to 1.36 m	−0.50	0.47	0.61	0.24	1.52	NS
Length of freestall						
1.84 to 2.18 m	Reference					
2.19 to 2.25 m	0.15	0.29	1.16	0.66	2.05	NS
2.26 to 2.32 m	0.00	0.31	1.00	0.54	1.84	NS
2.33 to 2.71 m	0.94	0.39	2.56	1.19	5.50	*

Continued

Table 1 (Continued). Hair loss at the hock: results of the multilevel model for associated risk factors (moderate or severe hair loss = 1, no or mild hair loss = 0)

Model term	Coefficient	SE	Odds ratio	95% CI 2.5%	95% CI 97.5%	*P*-value
Herd size[1]						
46 to 105 cattle	Reference					
106 to 145 cattle	−0.53	0.24	0.59	0.37	0.94	*
146 to 200 cattle	−0.68	0.30	0.51	0.28	0.91	*
201 to 394 cattle	−0.35	0.27	0.70	0.42	1.20	NS

[1]Indicates a risk factor common to both hair loss and ulceration.

[2]Indicates a risk factor common to both hair loss and swelling.

*$P < 0.05$.

between hair loss and swelling; 8, 5, and 11 risk factors were unique to hair loss, ulceration, and swelling, respectively. These results suggest that although some factors may be common between pairs of lesions, the underlying etiology and development of the different lesion presentations may in part differ and, therefore, it cannot be assumed that lesion progression is linear or for common reasons. This is particularly true of hock swelling, which shared only 1 risk factor with other lesion types. These findings are supported by the results of a previous longitudinal study (Livesey et al., 2002). Further work including longitudinal and interventions studies are required to advance our understanding of the development, resolution, and control of this prevalent and important disease.

As demonstrated by previous authors, locomotion score was positively correlated with hair loss and ulceration (Haskell et al., 2006; Fulwider et al., 2007; Kielland et al., 2009). The cause and effect in the relationship between locomotion score and hock score has not previously been investigated and cannot be established through data collected in a cross-sectional study. However within the United Kingdom, a high prevalence of both hock lesions and lameness exists (Barker et al., 2010). Previous work has demonstrated that lame cows lie down for longer periods of time (Chapinal et al., 2010), thereby increasing the time during which they are exposed to the lying surface and potentially at risk of developing hock lesions. Lameness may further alter lying and rising behavior by affecting the number and duration of individual lying bouts and the ease with which the animal rises from the stall. Alternatively, the presence of hock lesions may lead to disorders of gait due to mechanical restriction of joint flexion, infection at the site of the lesion, or pain associated with the lesion. It is, therefore, possible that in some herds, hock lesions may be directly responsible for the high levels of impaired locomotion and lameness that are observed. Given the significant effects of lameness on the production (Archer et al., 2010) and welfare (Whay et al., 1997) of dairy cows, it is important that further work is conducted to determine the link between these conditions.

The finding that dirtier cows had decreased odds of ulceration is contrary to previous findings (Regula et al., 2004; Zurbrigg et al., 2005). The physical presence of dirt at the hock may have a protective effect against the development of ulceration because it may provide a protective barrier. Alternatively, it may reflect either a management factor, be indicative of the behavior of the animal (e.g., the position of the cow within the stall), or be associated with one or more variables not measured here. It is also possible that fecal contamination masked ulcerative lesions, making them less visible to the observer, thereby decreasing either the recorded severity or number identified and scored.

Supporting the findings of other studies, mats and mattresses were associated with a high prevalence of lesions (Weary and Taszkun, 2000; Fulwider et al., 2007), although differences in lesion development between the 2 surface types have been observed (Livesey et al., 2002). In this study, the length of time that the mats or mattresses had been in the freestalls was also related to the development of hair loss. Older mats and mattresses may become less abrasive or more compliant as the surfaces ages, decreasing the risk of lesion development. Mat and mattress manufacturers should be made aware that their products are a risk factor for the development of hock lesions so that suitable surfaces can be developed which decrease these risks while maintaining key product characteristics (e.g., cow comfort, durability, and a non-slip surface).

As demonstrated in previous work, straw was associated with a lower prevalence of hair loss and swelling than other bedding types within freestalls (Rutherford et al., 2008). However, for hair loss, this only held true for whole straw and not for chopped straw. Observations made during the study suggested that chopped straw was blown onto the front of the freestall, so that no or very little bedding might be at the rear of the

Table 2. Ulceration at the hock: results of the multilevel model for associated risk factors (ulceration = 1, no ulceration = 0)

Model term	Coefficient	SE	Odds ratio	95% CI 2.5%	95% CI 97.5%	P-value
Locomotion[1]						
Score 0	Reference					
Score 1	0.23	0.13	1.26	0.98	1.62	NS
Score 2	0.43	0.11	1.54	1.24	1.91	*
Score 3	0.66	0.17	1.93	1.39	2.70	*
Days of winter housing[1]						
2 to 40 d	Reference					
41 to 76 d	0.17	0.21	1.19	0.79	1.79	NS
77 to 111 d	0.68	0.21	1.97	1.31	2.98	*
>112 d	0.27	0.21	1.31	0.87	1.98	NS
Mean milk yield[1]						
2.4 to 20.7 kg	Reference					
20.8 to 26.9 kg	0.26	0.14	1.26	0.96	1.66	NS
27.0 to 33.8 kg	0.29	0.14	1.34	1.02	1.76	*
33.9 to 58.1 kg	0.27	0.15	1.31	0.98	1.76	NS
Total animal cleanliness score						
1 to 12	Reference					
13	−0.01	0.13	0.99	0.77	1.28	NS
14 to 27	−0.27	0.11	0.76	0.62	0.95	*
Freestall base material[1]						
Mattress	Reference					
Concrete	−1.34	0.29	0.26	0.15	0.46	*
Mat	−0.06	0.25	0.95	0.58	1.55	NS
Other	−1.06	0.36	0.35	0.17	0.70	*
Freestalls with broken side rails (not protruding)						
0.0%	Reference					
0.1 to 2.9%	0.11	0.33	1.12	0.58	2.13	NS
3.0 to 61.1%	−0.92	0.33	0.40	0.21	0.76	*
Freestalls with interrupted bob zone						
0.0 to 52.6%	Reference					
52.7 to 91.7%	0.35	0.24	1.42	0.89	2.27	NS
91.8 to 100.0%	0.53	0.24	1.70	1.06	2.72	*
Freestalls with foreign objects present						
0.0%	Reference					
0.1 to 100.0%	1.05	0.38	2.86	1.36	6.02	*
Herd size[1]						
46 to 105 cattle	Reference					
106 to 145 cattle	0.17	0.32	1.19	0.63	2.22	NS
146 to 200 cattle	0.56	0.34	1.75	0.90	3.41	NS
201 to 394 cattle	0.85	0.32	2.34	1.25	4.38	*
Floor type of freestall yards						
Smooth concrete	Reference					
Textured concrete	0.74	0.41	2.10	0.94	4.68	NS
Textured and grooved concrete	0.57	0.55	1.77	0.60	5.20	NS
Grooved concrete	1.33	0.41	3.78	1.69	8.45	*
Other	0.55	0.49	1.73	0.66	4.53	NS

[1]Indicates a risk factor common to both hair loss and ulceration.

*$P < 0.05$.

stall. Although automated systems for bedding cubicles with straw decrease the time required, to lower the risk of hock lesion development, care should be taken to ensure complete coverage of the bed. Compared with straw, sawdust or wood shavings were associated with higher odds of both hair loss and swelling. Sawdust on mats or mattresses is one of the most common freestall bedding combinations currently used in the United Kingdom. Although sawdust has several management advantages, it is important that producers are made aware of the risks it poses to the development of hock lesions so that informed decisions can be made on the relative merits of different stall bedding types. This is especially true when significant alterations to existing buildings or new housing are being planned.

A notable risk factor, which to the authors' knowledge has not been previously examined, is the application of hygiene products to freestall beds. In the UK, a variety of products are applied to freestalls as disinfection and desiccation agents (e.g. lime powder- and formaldehyde-based compounds). Greater quantities of hygiene products and a greater frequency of appli-

Table 3. Swelling at the hock: results of the multilevel model for associated risk factors (moderate or severe swelling = 1, mild swelling = 0)

Model term	Coefficient	SE	Odds ratio	95% CI 2.5%	95% CI 97.5%	*P*-value
BCS						
1 to 1.5	Reference					
2	−0.22	0.09	0.80	0.67	0.96	*
2.5 to 3	−0.34	0.11	0.71	0.57	0.88	*
3.5 to 4.5	−0.58	0.15	0.56	0.42	0.75	*
DIM						
2 to 101 d	Reference					
102 to 166 d	0.27	0.10	1.31	1.08	1.59	*
167 to 269 d	0.35	0.11	1.42	1.14	1.76	*
270 to 979 d	0.61	0.13	1.84	1.43	2.37	*
Most recent milk yield						
2.6 to 19.6 kg	Reference					
19.7 to 26.3 kg	0.34	0.12	1.40	1.11	1.78	*
26.4 to 33.7 kg	0.08	0.13	1.08	0.84	1.40	NS
33.8 to 67.8 kg	0.34	0.14	1.40	1.07	1.85	*
Slips while rising						
Slips	Reference					
Does not slip	−2.14	0.96	0.12	0.02	0.77	*
Contact with furniture while rising						
Makes contact	Reference					
Does not make contact	−0.44	0.18	0.64	0.45	0.92	*
Freestall bedding material[1]						
Sawdust or wood shavings	Reference					
Sand	−0.67	0.44	0.51	0.22	1.21	NS
Whole straw	−0.92	0.30	0.40	0.22	0.72	*
Chopped straw	−1.35	0.41	0.26	0.12	0.58	*
Waste wood or paper	−0.61	0.49	0.54	0.21	1.42	NS
Mean depth of bedding material						
0.00 to 0.02 m	Reference					
0.03 to 0.04 m	−0.51	0.36	0.60	0.30	1.22	NS
0.05 to 0.06 m	−1.25	0.37	0.29	0.14	0.59	*
0.07 to 0.12 m	−0.98	0.33	0.38	0.20	0.72	*
Hygiene products applied to freestalls						
0.00 to 0.03 kg/stall per week	Reference					
0.04 kg/stall per week	0.37	0.37	1.45	0.70	2.99	NS
0.05 to 0.09 kg/stall per week	0.97	0.34	2.64	1.35	5.14	*
0.10 to 0.70 kg/stall per week	0.09	0.30	1.09	0.61	1.97	NS
Distance from brisket positioner to rear of freestall						
1.72 to 1.78 m	Reference					
1.79 to 1.84 m	−0.58	0.26	0.56	0.34	0.93	*
1.85 to 2.05 m	−0.27	0.29	0.76	0.43	1.35	NS
2.06 to 2.32 m	−0.22	0.28	0.80	0.46	1.39	NS
Freestalls facing a wall						
0.0 to 34.8%	Reference					
34.9 to 52.7%	0.17	0.20	1.19	0.80	1.75	NS
52.8 to 80.5%	0.02	0.19	1.02	0.70	1.48	NS
80.6 to 100.0%	−0.63	0.22	0.53	0.35	0.82	*
Freestalls with broken neck rails (not protruding)						
0.0%	Reference					
0.1 to 0.9%	−0.18	0.23	0.84	0.53	1.31	NS
1.0 to 57.1%	0.45	0.21	1.57	1.04	2.37	*
Stocking rate						
0.7 to 0.9 cubicles/cow	Reference					
1.0 cubicles/cow	0.40	0.18	1.49	1.05	2.12	*
1.1 to 1.2 cubicles/cow	0.60	0.18	1.82	1.28	2.59	*
1.3 to 1.9 cubicles/cow	0.04	0.22	1.04	0.68	1.60	NS

[1]Indicates a risk factor common to both hair loss and swelling.

*$P < 0.05$.

cation were associated with greater odds of hair loss and swelling. Hygiene products are likely to come into direct contact with an animal's skin and may directly increase the risk of lesion development. This may be due to the irritating nature of these products, which could potentially cause chemical burns when moisture is present. Hygiene products are applied to decrease bacterial contamination of the bed and decrease the risk of disease (e.g., mastitis). Although insufficient evidence exists from this study alone to advocate their complete removal, the quantity used and frequency of application should be carefully considered, especially on units with a high prevalence of hock lesions.

Freestall design has previously been linked to the prevalence and severity of hock lesions (Weary and Taszkun, 2000; Fulwider et al., 2007; Kielland et al., 2009). In the herds examined here, the dimensions and the condition of the freestalls affected the odds of hair loss, ulceration, and swelling developing. Freestall design has also been demonstrated to affect the use of freestalls by dairy cows (Tucker et al., 2004; Veissier et al., 2004; Tucker et al., 2006), with delayed and abnormal risings positively correlated with injuries (Regula et al., 2004). The freestall design features highlighted in the current study may have affected the position of the animal in the freestall and the distance that she maintained from the edge of the bed, the angle at which she laid, and the ease with which she was able to lay down, reposition herself, and lunge and rise. Poor or inappropriate freestall design may mean that an animal is forced to shuffle around the freestall before attempting to rise, or may come into contact with the freestall fittings when standing, lying, or changing position, increasing the risk of lesion development.

Whatever the actual relationship, what is apparent from the results of this and other cross-sectional studies is that several aspects of freestall design are important risk factors in the development of all types of hock lesions. The interactions between the cow, her behavior, and the stall design are likely to be complex and interrelated. An interesting observation from this study is that the odds of ulceration decreased significantly as the proportion of freestalls with broken side rails increased. This may indicate that over time, the cows themselves have succeeded in damaging the freestalls to meet with their actual requirements or preferences, in a way which decreased the risk of developing a hock lesion. Carefully designed intervention studies are needed to further current understanding of stall-based risk factors for hock lesions so that future building design can be optimized to ensure animal health and welfare.

Freestalls containing foreign objects posed a greater risk for ulceration than freestalls without. The foreign objects may cause direct damage to the hock as the cow is forced to lie on them. Once trauma is inflicted, repeated exposure to the lying surface may prevent or delay healing, increasing lesion prevalence. Alternatively, foreign objects may have affected the ability of the animal to use the freestall or may have forced animals to alter their lying or rising behavior in a way which increased the risk of developing a lesion. Whatever the root cause, it is important that stall-housed cows are provided with a comfortable bed, free of debris and other extraneous material.

To consider the risk factors associated with the lesion presentations in multilevel models, binary indicators were created for each of the outcome variables. The thresholds used were chosen to differentiate what the authors considered to be the most important biological lesion categories. The majority of cows had some degree of hair loss, no ulceration, and mild or no swelling, so these were taken as reference categories. The risk factors associated with more severe lesion manifestations (i.e., moderate or severe hair loss, any degree of ulceration, and moderate or severe swelling) could, therefore, be determined.

Although swelling was scored on a 4-point scale, none of the hocks scored in the 63 freestall housed herds were score 0. The scale was designed previously for the purpose of assessing cows across all housing systems, including those that are straw or pasture based. Within these systems, a greater proportion of animals are observed with no identifiable swelling than within freestalls. The scoring system has been used in previous studies (Whay et al., 2003; Huxley et al., 2004), and the current observer was trained by one of the previous authors (J. Huxley).

This paper further adds to the weight of evidence describing risk factors associated with the development of hock lesions in dairy cattle. Several risk factors identified in this study have been recognized by previous authors, including milk yield (Rutherford et al., 2008), parity (Weary and Taszkun, 2000), breed (Alban et al., 1996), DIM (Kielland et al., 2009), and herd size (Rutherford et al., 2008). Although the mechanisms by which the majority of these factors might contribute to lesion development can be hypothesized, some associations cannot be readily explained. Additionally, the associations found here and in other cross-sectional studies do not demonstrate causality and, hence, some of the risk factors identified may be markers for other variables that have not been measured. In this study, a large sample of cows was randomly selected from within 63 herds across the Midlands area of the United Kingdom. Farms were selected based on inclusion criteria and their willingness to participate. When considering these results, it is important to note that the agreement of farmers to participate in studies of this nature introduces an unavoidable bias. Any bias is difficult to quantify, but could be related to potential differences in overall herd management, which could be either positive or negative in effect. In addition, due to the regional sample, the study population may not be representative of the UK dairy cow population as a whole. The population sampled may, therefore, have been skewed toward the best or worst herds in terms of prevalence of hock lesions or overall cattle health and welfare, although examination of the cows did not suggest this to be the case.

CONCLUSIONS

Hock lesions were prevalent in freestall-housed dairy cows across the Midlands region of the United Kingdom. Moderate and severe hair loss and swelling, and ulceration of any degree, were each associated with several variables at the level of the cow, lying environment, and the herd. The risk factors common to both hair loss and ulceration were locomotion score, number of days of winter housing, milk yield, freestall base material, and herd size. The existence of several differential risk factors between the 2 lesion presentations suggests that ulceration may not always be a direct extension of hair loss. Of the 12 risk factors associated with swelling at the hock, only bedding material was common to another lesion presentation (hair loss), suggesting that swelling may have a different etiology than hair loss and ulceration. However, more longitudinal work is required to fully understand the development of these lesion presentations and the associations among them. The variables associated with the lesions indicate the importance of factors that potentially affect the lying and rising behavior of the cow, including freestall structure and design, and the lying surface. The mechanisms by which some of the factors affect the development of hock lesions are unclear; longitudinal and intervention studies are required to further our understanding of the prevalence and control of this important and common problem.

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