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Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales

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ABSTRACT

Visits were made to 205 dairy farms in England and Wales between October 2006 and May 2007 by 1 or more of 4 researchers. At each visit, all milking cows were locomotion scored (lameness scored) using a 4-point scale (0 = sound locomotion, 1 = imperfect locomotion, 2 = lame, 3 = severely lame). The mean prevalence of lameness (scores 2 and 3) across the study farms was 36.8% (range = 0–79.2%). On each farm, the presence within the housing and grazing environments of commonly reported risks for increased lameness was recorded. Each farmer was interviewed to gauge the ability of the farm staff to detect and treat lameness. A multivariable linear regression model was fitted. Risk factors for increased lameness were the presence of damaged concrete in yards, cows pushing each other or turning sharply near the parlor entrance or exit, cattle grazing pasture also grazed by sheep, the use of automatic scrapers, not treating lame cows within 48 h of detection, and cows being housed for 61 d or longer at the time they were locomotion scored by the visiting researcher. Having a herd consisting entirely of a breed or breeds other than Holstein-Friesian was associated with a reduction in lameness prevalence compared with having a herd consisting entirely of Holstein-Friesians.
Key words: dairy cow, lameness prevalence, risk, general linear model

INTRODUCTION

Recent estimates of the prevalence of lameness on dairy farms in the United Kingdom include 24% for organic herds (Huxley et al., 2004), 15% for grazing herds, and 39% for zero-grazing herds (Haskell et al., 2006), and 16.2, 16.3, and 19.3% in autumn, winter, and spring, respectively (Rutherford et al., 2009). Such high prevalence figures are a welfare concern given the lowered nociceptive thresholds and, by inference, increased pain reported for lame cows compared with sound cows (Whay et al., 1997). In addition to impaired welfare of the individual animals concerned, significant production losses have been widely reported for lame cattle, including milk loss (Amory et al., 2008), reduced fertility (Garbarino et al., 2004), and increased culling rates (Booth et al., 2004).

In recent years, evidence of risks for increased lameness associated with the environment in which the cow lives has mounted. The importance of providing comfortable lying spaces for cows in order to facilitate increased lying times was highlighted by Cook and Nordland (2009). Increased lameness has been reported where the dimensions of free-stalls were poor (Faull et al., 1996), insufficient bedding was provided on free-stalls (Cook et al., 2004; Barker et al., 2007), and the quality of bedding was poor (Fregonesi et al., 2007). Poor walking surfaces in yards (Dembele et al., 2006) and on tracks (Chesterton et al., 1989) have also been associated with increased lameness. Exposure to slurry and slurry-contaminated water in the housed environment is associated with softer claw horn (Borderas et al., 2004), increased claw horn lesions (Gregory et al., 2006), and increased digital dermatitis (Somers et al., 2005).

The management of cattle within their environments is also important, but this is more difficult to assess and its effects are more difficult to quantify with infrequent visits to farms. One important area is the management of claw health. Klaas et al. (2003) reported that claw overgrowth was associated with increased risk of lameness. Several positive effects have been reported for routine preventive claw trimming of cows, including an increase in the surface area of the claw that is weight bearing (Van der Tol et al., 2005), improved walking characteristics (Aoki et al., 2006), and reduced odds for lameness (Manske et al., 2002). Although some effects of routine preventative claw trimming have been investigated, there remains a paucity of information about how and when stockpersons treat lame cows and how successful these treatments are. Whay et al. (2002) reported variation in the ability of farmers to identify lame cows and reported that in most cases, compared with trained researchers, farmers underestimated the number of lame cows when using locomotion scoring.

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Table 1. Locomotion scoring system

Score	Description
0	Sound. Walks confidently, with even weight on all 4 feet; tracks up (hind feet in prints of fore feet); no swinging of legs inward or outward.
1	Imperfect locomotion. May walk cautiously, possibly because of tenderness, OR does not track up, OR legs swing out or in, but no obvious limp.
2	Lame. Definite limp (foot fall uneven, dew claws on affected limb do not drop as far) OR arched spine. A favored limb will move more quickly than the lame limb. Speed of walk not noticeably affected.
3	Severely lame. Cannot walk at a brisk human pace. Animal shows obvious signs of limb pain (e.g., reluctance to bear weight, very obvious shifts in body posture).

Further investigation of the aspects of herd management on dairy farms that affect the detection, handling, treatment, and after care of lame cows is still required.

MATERIALS AND METHODS

Recruitment

Farmers were initially recruited through 4 United Kingdom dairy companies for a larger ongoing study of lameness in dairy cattle. Letters detailing the study were posted by the dairy companies to 782 farmers. Follow-up telephone calls were made to the farmers who expressed an interest in taking part in the study to confirm that their farms meet the recruitment criteria (herd size greater than 35 cows and an intention to continue dairying for the next 4 yr). From these telephone calls, 198 farmers (25.3%) were enrolled in the study. A further 98 farmers were telephoned directly using contact details from the telephone directory, 29 (29.6%) of whom were enrolled.

Data Collection

A single visit was made by 1 or more of 4 researchers to each of 227 dairy farms between October 2006 and May 2007. Farms were located in southwest England, southern England, south and west Wales, and central England. All cows in the milking herd at the time of the visit were assessed using the 4-point locomotion scoring scale described in Table 1. Cows were locomotion scored either as they exited the parlor or in a loafing yard. The 4 researchers were initially trained by 1 experienced locomotion scorer. They then continued to participate in regular group scoring sessions during the data collection period to minimize any potential variation between the locomotion scores recorded on different farms. Percentage agreement and kappa values were calculated for each researcher compared with each of the other 3 researchers.

Basic information about the farm system was gathered either during the initial telephone conversation with the farmer or on arrival at the farm. This included herd size, yield, calving pattern, type of system (conventional or organic), and breed. A structured risk assessment of the farm environment, including floor surfaces, lying surfaces, building layout, cow tracks, and gateways, was completed and the presence or absence of potential risks for lameness was noted. Each farmer was interviewed to gather information on risks that could not be assessed using observations at a single time point, such as information on lameness treatment protocols, markers for failures in the management of lameness, nutrition, and daily routines (e.g., scraping frequency). All aspects of the farm assessment (i.e., lameness scoring, risk assessment, and farmer interview) were completed by 1 or more of 4 trained researchers.

Analysis

Data from 7 farms were not put forward for the analysis because the farmers withdrew from the study immediately after the first visit. Risk assessment data or management questionnaires from a further 15 farms were incomplete, so their data were excluded. The risk assessments and responses from the farmer interview on 205 farms were used to generate explanatory variables included in univariable linear regression models where the lameness prevalence (percentage of scores 2 and 3) was the outcome variable. The normality of the outcome variable, lameness prevalence, was tested using the Kolmogorov-Smirnov test of composite normality and was found not to deviate significantly from normal ($P = 0.5$). Where appropriate, some categories summarized in Table 2 were grouped to increase the number of farms represented in a given category. Only explanatory variables with greater than 20 farms represented in each category were considered in the modeling, with the exception of breed. This was considered an important variable to consider, but it was not possible to create biologically sensible categories of greater than 20 farms. Variables related to the feed ration were excluded because of the large quantities of missing data. Variables were put forward for the multivariable analysis where $P < 0.1$ at the univariable level. Two submodels were generated, the first of which (submodel 1) contained variables relating to the housed and grazing environments (Table 3). These were measures of the potential risks for new cases of lameness present in the areas accessed by the cows (e.g., free-stall type or track surface). The second submodel (submodel 2) included variables related to the management of the farm system (Table 4) that reflected the general standards of care taken over the routine management of lameness and lameness-related factors on the farm (e.g., lameness treatment protocols or frequency of slurry scraping). Breed was included in submodel 1 because it was likely to influence the ability of cows to cope in different farm environments but was less likely to affect the general management of the system by the farmer. Conversely, whether a farm is organic or conventional may affect the way in which the management of lameness is approached by farm staff but would not affect the actual farm environment, so this variable was included in submodel 2. The length of time the cows had been housed at the time of the locomotion scoring visit was also included in submodel 2 to account for any changes of management associated with the different housing locations. Significant variables from both submodels were then added into an overall model (Table 5). All models were constructed using a backward elimination. Explanatory variables were retested in each of the multivariable models to check for any confounding. All statistical analyses were carried out using SPlus Version 6.1 Professional (Insightful Corp., Basingstoke, UK).

RESULTS

The mean prevalence of lameness (scores 2 and 3) across the study farms was 36.8% (SE ±1.3%); the range was 0 to 79.2%. The prevalence of score 2 (lame) cows was 31.5% (SE ±1.08%); the range was 0 to 72.5%. The prevalence of score 3 (severely lame) cows was 5.3% (SE ±0.42); the range was 0 to 31.2%. The mean herd size was 163 cows (SE ±7.46); the range was 37 to 642 cows. The mean annual yield per cow was 7,202 L (SE ±115); the range was 2,500 to 11,200 L. The predominant breed was Holstein-Friesian; however, several other breeds were represented, including Jersey and Dairy Shorthorn. The main categorical variables with the associated mean lameness prevalence per category are summarized in Table 2.

The percentage agreement between the paired observers ranged from 61.3 to 83.3% when comparing the whole 4-point scale and from 83.9 to 96.8% when comparing lame versus nonlame cows as in the outcome variable. Kappa values between the paired observers ranged from 0.67 (moderate) to 0.93 (good) when comparing lame with nonlame cows.

In submodel 1 (winter housing and grazing environment), the use of automatic scrapers compared with not having automatic scrapers and the use of less than 20 mm of bedding materials on free-stalls with a solid base (i.e., concrete alone or with mats or mattresses) compared with using 100 mm or more of bedding on free-stalls with a solid base were both associated with increased lameness when added to the model independently. However, both variables could not be retained in the model at the same time because of a high degree of colinearity between the variables. The models were compared using Akaike's information criterion, and the model containing the depth of bedding variable was rejected. The results of submodel 1 (winter housing and grazing environment risks) and submodel 2 (management risks) are presented in Tables 3 and 4, respectively. Significant variables from these submodels that failed to remain in the final overall model because of confounding were the presence of sharp and eroded concrete (i.e., surface of the concrete eroded by effluent, exposing sharp surface beneath) in yards or passageways; no active observation of cows for lameness by farmers; and the presence of severe heel erosion, interdigital growths, or toe necroses in first-lactation heifers as reported by the farmers (i.e., the farmer responded yes when asked whether any of these lesions hade been observed in first-lactation heifers).

The variables associated with an increase in lameness prevalence in the overall model were the presence of damaged concrete (other than that caused by erosion) in yards or alleys, cows pushing each other or sharp turns occurring near the parlor entrance or exit, cattle grazing pasture also grazed by sheep, and not treating lame cows within 48 h of detection by the farmer; having cows housed for 61 d or more at the time of the locomotion scoring visit to the farm was associated with increased lameness compared with being housed for 0 to 60 d. Having a herd consisting entirely of a breed or breeds other than Holstein-Friesian was associated with a reduction in lameness prevalence compared with having a herd consisting entirely of Holstein-Friesians. On farms where the farmer reported that no digital dermatitis was present, there was a lower prevalence of lameness. The presence of free-stalls with abrasive lying surfaces was associated with an increased prevalence of lameness in the overall model after the process of adding back all previously nonsignificant variables. Herd size was added to the model but was not associated with an increase in prevalence of lameness despite such an association being present at the univariable level. The mean annual yield per cow was also tested in the model. The overall model became nonsignificant so this model is not presented, but the effects of the addition of yield on the model variables are described below. Cows pushing each other or sharp turns occurring near the parlor entrance or exit and having no digital dermatitis on the farm (as reported by the farmer) became nonsignificant when yield was added to the overall model. Although still significant, the protective effect of having a breed or breeds other than Holstein-Friesian was reduced with the addition of yield to the overall model.

DISCUSSION

The mean prevalence of lameness of 36.8% in this study should be a great concern to all associated with the dairy industry, particularly given that the highest recorded farm prevalence was over 70%. Also of concern was the high prevalence of cows with the most severe locomotion score. The prevalence of lameness recorded in this study is greater than the recent estimates of 15% for grazing herds (Haskell et al., 2006) and 16.2, 16.3, and 19.3% in autumn, winter, and spring, respectively (Rutherford et al., 2009), but closer to the figures reported by Haskell et al. (2006) for zero-grazed herds (39%). Care must be taken when comparing the figures above with this study because of the different scoring systems used. A comparable scoring system was used by Huxley et al. (2004) where the prevalence was 24%

Table 2. Descriptive summary of the main categorical variables

Variable	Category	No. of farms	Mean lameness prevalence (%)
Calving pattern	Year round	112	37.5
	Block calve—autumn	17	44.1
	Block calve—spring	13	27.7
	Other	50	36.6
	Unknown	13	29.1
Length of time from cows being housed to visit	0–60 d	46	27.7
	61–120 d	54	39.9
	121–180 d	59	40.4
	>180 d	22	47.0
	Not currently housed	12	20.2
	Never housed	2	20.0
	Zero grazed	4	42.0
	Unknown	6	41.1
Conventional or organic	Conventional	137	40.5
	Organic	68	29.3
Breed	All cows Holstein	23	45.3
	All cows Holstein × Friesian crosses	137	37.8
	All cows Friesian	9	38.1
	All cows of one breed other than Holstein-Friesian	8	13.0
	Mixture of breeds, with >10% of cows not Holstein-Friesian	7	46.2
	Mixture of breeds, with <10% of cows not Holstein-Friesian	14	31.6
	Mixture of breeds other than Holstein-Friesian	7	15.8
Main housing type for milking cows	Free-stall house	169	38.8
	Deep straw yard	36	27.1
Free-stall bedding type	Straw	90	37.2
	Sawdust	39	43.0
	Sand	22	39.1
	Paper	6	31.8
	No bedding	1	59.0
	Multiple bedding types	3	53.6
	Not recorded	8	34.5
Depth of bedding used	<20 mm bedding	32	45.4
	20–99 mm bedding	54	37.6
	>99 mm bedding over solid free-stall base	25	35.9
	>99 mm bedding over soft free-stall base	12	37.9
	Mixed bedding depths	1	67.9
	Unknown	45	37.9
Slurry scraping method	Automatic scrapers	30	44.5
	No automatic scrapers	173	35.5
Footbathing frequency	Fewer than once a week	62	38.1
	Once a week or more	65	44.7
	Never	76	28.7
	Unknown	2	50.0
Digital dermatitis	Digital dermatitis present on farm	162	39.9
	Digital dermatitis not reported on farm	42	24.3
	Unknown	1	56.0

Table 3. Risk factors in housing and pastures associated with increased lameness (submodel 1: winter housing and grazing environment risks)[1]

Item	No. of farms	Coefficient	SE	P-value
Intercept		22.57	3.03	0.00
Damaged concrete				
No (reference category)	68			
Yes	112	7.40	2.55	0.00
Sharp and eroded concrete				
No (reference category)	132			
Yes	48	5.00	2.82	0.08
Pushing or sharp turning near parlor exit or entrance				
No (reference category)	143			
Yes	37	6.27	3.15	0.05
Use of automatic scrapers				
No (reference category)	152			
Yes	28	10.16	3.46	0.00
Cattle grazing on pasture also grazed by sheep				
No (reference category)	102			
Yes	78	7.87	2.45	0.00
Herd size (per 100 cows)		1.48	1.23	0.23
Breed				
Holstein-Friesian (reference)	124			
Whole herd pedigree Holstein or pedigree Friesian	26	4.50	3.47	0.20
Mixture of Holstein-Friesian and other breeds	19	1.10	3.94	0.78
Whole herd comprises breed(s) other than Holstein-Friesian	11	−20.52	5.17	0.00

[1]Variables presented are categorical with the exception of herd size, which is continuous.

in the organic herds studied. This compares well with 29% in the organic herds in this study (Table 2). Having a lower prevalence in organic herds compared with nonorganic herds is in agreement with Rutherford et al. (2009). Although the farms enrolled in this study do not represent the whole of the United Kingdom geographically, the large number of farms and range of herd sizes, production levels, and farm types ensures that the study represents a diverse subsection of United Kingdom dairy farms.

The current study design allows several variables to be compared while the variation in the large study

Table 4. Management risk factors associated with increased lameness (submodel 2: management risks)[1]

Item	No. of farms	Coefficient	SE	P-value
Intercept		21.75	3.31	0.00
Time to treatment				
Cows treated by farmer ≤48 h after diagnosis of lameness	56			
Cows treated by farmer >48 h after diagnosis of lameness	132	6.58	2.63	0.01
Observation of cows for lameness (by farmer)				
Active observation of cows for lameness	100			
No active observation of cows for lameness	88	7.77	2.53	0.00
Severe heel erosion, interdigital growths, or toe necrosis occurring in first-lactation heifers (as reported by farmer)				
No	161			
Yes	27	5.94	3.39	0.08
Digital dermatitis not reported on farm				
No	149			
Yes	39	−8.07	2.96	0.01
Organic or conventional				
Conventional	129			
Organic	59	−4.56	2.63	0.08
Length of time between date cows were housed and date of lameness scoring visit				
0–2 mo	39			
2–4 mo	51	12.01	3.23	0.00
4–6 mo	56	12.55	3.28	0.00
>6 mo	25	12.41	4.11	0.00
Cows not housed	12	0.19	5.24	0.97
Unknown	5	9.75	7.46	0.19
Herd size (per 100 cows)		1.66	1.16	0.16

[1]Variables presented are categorical with the exception of herd size, which is continuous.

Table 5. Risk factors associated with increased lameness (overall model)

Item	No. of farms	Coefficient	SE	P-value
Intercept		14.12	3.70	>0.01
Time to treatment				
Cows treated by farmer ≤48 h after diagnosis of lameness	56			
Cows treated by farmer >48 h after diagnosis of lameness	132	6.81	2.53	0.01
Digital dermatitis not reported on farm				
No	149			
Yes	39	−6.89	3.01	0.02
Length of time between date cows were housed and date of lameness scoring visit				
0–2 mo	39			
2–4 mo	51	13.73	3.25	>0.01
4–6 mo	56	14.14	3.41	>0.01
>6 mo	25	16.38	4.07	>0.01
Cows not housed	12	−5.13	5.40	0.34
Unknown	5	13.39	6.79	0.05
Damaged concrete				
No (reference category)	68			
Yes	112	8.61	2.28	>0.01
Abrasive lying surface in cubicles				
No (reference category)	132			
Yes	48	4.75	2.32	0.04
Pushing or sharp turning near parlor exit or entrance				
No (reference category)	143			
Yes	37	6.20	2.87	0.03
Use of automatic scrapers				
No (reference category)	152			
Yes	28	7.50	3.06	0.02
Cattle grazing on pasture also grazed by sheep				
No (reference category)	102			
Yes	78	6.30	2.22	0.01
Breed				
Holstein-Friesian (reference)	124			
Whole herd pedigree Holstein or pedigree Friesian	26	1.84	3.15	0.56
Mixture of Holstein-Friesian and other breeds	19	0.12	3.79	0.97
Whole herd comprises breed(s) other than Holstein-Friesian	11	−17.99	4.92	>0.01
Herd size (per 100 cows)		0.19	1.15	0.87

[1]Variables presented are categorical with the exception of herd size, which is continuous.

population is adjusted for. However, there are limitations to the analyses performed. It is not possible to prove a causative relationship between the variables measured and an increased risk of lameness. Indeed, it is possible that the association between lameness and some variables occurs as a result of increased lameness. For example, a farmer with the problem of an infectious cause of lameness may choose to footbath more frequently, resulting in an association between lameness and increased footbathing. These limitations should be considered when interpreting the results of this study.

Many of the variables related to lameness in the overall model were related to the winter housing environment. The use of automatic scrapers was associated with an increased risk of lameness in this study and previously (Barker et al., 2007). One explanation for this association is that the movement of the automatic scraper through the house disturbs the cows, forcing them to move out of its path as they feed or loaf in the alleyways. Where cows are in close proximity to each other (e.g., while feeding at the feed barrier), they may not be able to see the approaching automatic scraper and are therefore forced to make hurried movements out of its path or may not be able to find a clear route to move out of the path of the moving scraper. Stefanowska et al. (2001) reported that 94% of incidents of tripping or stumbling by cows in houses with automatic scrapers resulted from direct contact with the scrapers. These trips and stumbles may result either in excessive forces passing through the claw as the cow seeks to regain her balance or in poor foot placement, leading to abnormal claw loading. Both of these scenarios increase the risk of claw horn lesions, as could physical damage caused by direct contact with the scraper mechanism.

An alternative, though perhaps less favorable, explanation for the association between automatic scrapers and lameness is that digital dermatitis is an intermediate factor. An increased risk of digital dermatitis was reported by Somers et al. (2005) where automatic scrapers run over solid alley floors compared with slatted alley floors. The wave of slurry that moves in front of automatic scrapers as they run down the alley is greater for scrapers over solid floors than over slatted floors. The skin around the coronary band, where digital dermatitis lesions are commonly found, is coated with slurry on cows walking or standing in the path of the wave of slurry. It is possible that the poor hygiene of feet and legs in dairy cows provides more favorable conditions for digital dermatitis. However, this remains speculative because the route of new infection with digital dermatitis and the transmission of digital dermatitis between cows are yet to be defined.

Barker et al. (2007) reported a positive correlation between automatic scrapers (a significant risk for poor locomotion scores) and bedding free-stalls with sawdust on mats or mattresses. In this study and the one described by Barker et al. (2007), the high degree of correlation between lying surface and scraping method precluded the retention of the lying type variable in the overall model. Nevertheless, this is an important finding and offers an alternative explanation for the association between automatic scrapers and lameness in which automatic scrapers are a proxy for poor free-stall comfort. Because of the nature of slurry collection and handling with automatic scrapers, it is common to use a sparse quantity of bedding substrate on the free-stall base or intermediate surface. There are well-documented associations between poor free-stall comfort and shorter lying times (Tucker et al., 2003) and between shorter lying times or increased standing times and increased claw lesions (Singh et al., 1993). Cow comfort is also likely to be impaired where the lying surface is abrasive, either as a result of an abrasive bedding type, abrasive free-stall base or mattress surface, or both together, explaining the association between abrasive lying surfaces and increased lameness.

The presence of damaged concrete in yards or alleyways was associated with an increase in lameness in the overall model. There was also a trend for increased lameness where there were areas of concrete that were sharp or eroded in the submodel, but this was confounded by the damaged concrete variable and was not significant in the overall model. We hypothesize that these surfaces are uncomfortable for cows to stand or walk on and therefore would lead to altered weight bearing because cows move their weight away from the limb placed on the most unfavorable surface (Neveux et al., 2006). The uneven nature of the areas of damaged concrete can also lead to the claws of cows being only partially supported by the floor surface, which will alter the forces exerted within the claw (Hinterhofer et al., 2006). Abnormal loading both between and within the claw capsules increases pressure on the sensitive tissues within the claw and can disrupt normal horn growth, leading to formation of poor-quality claw horn and increased risk of claw lesions (Hoblet and Weiss, 2001). A further explanation for the detrimental effect of rough, sharp, or eroded concrete is that these surfaces have higher frictional properties and result in increased wear of the claw horn. The resulting thin horn of the sole is at increased risk of penetration by foreign bodies and the white line more is prone to separation.

Slippery floor surfaces are associated with altered gait (Flower et al., 2007) and increased lameness (Faull et al., 1996; Dembele et al., 2006). A similar association was also recorded at the univariable level for slippery concrete; however, this variable did not remain in the multivariable models.

Abnormal loading of the claw and altered forces within the claw occur where cows are forced to twist and turn sharply and may explain the increased prevalence of lameness associated with pushing or sharp turning near parlor exits or entrances in the overall model. Pushing and turning near the parlor typically occurred on the participating farms when either the parlor design was poor or the cows were pushed into too small a space in the collecting yard by either backing gates or farm staff.

Wassink et al. (2003) reported common pathogenesis between the spirochete associated with digital dermatitis in cattle and the spirochetes associated with contagious ovine digital dermatitis. Similarly, Dhawi et al. (2005) reported common pathogenesis between digital dermatitis-associated spirochetes and those associated with severe virulent ovine foot rot. Species of treponema associated with digital dermatitis in cattle were recently isolated from contagious ovine digital dermatitis lesions in sheep (Sayers et al., 2009). These results raise the possibility of transmission between cattle and sheep, offering an explanation for the association between an increased prevalence of lameness and the grazing of cows on pasture also grazed by sheep in the overall model.

Gaining full insight into the attitudes of stock persons toward both their cattle and the management tasks required for maintaining good animal health is difficult in the context of a large study using multiple farms where only a limited amount of time can be spent making observations on the farm. In this research, a farmer interview was used to assess how and when cows were diagnosed as lame and treated for lameness because it was not possible to directly observe the stock persons carrying out treatment of lame cows or routine claw trimming practices.

Lack of prompt treatment of lame cows by farmers (i.e., the farmers replied that they did not treat all cows within 48 h of diagnosing them as lame) was associated with increased lameness prevalence in the overall model. Indeed, in some cases cows were not treated until the next visit by the routine foot trimmer, up to 6 wk later.

It is likely that such delays in treatment would result in increasing severity of lesions and therefore delayed recovery. Inadequate detection and treatment of lameness was associated with both moderate and severe lameness in a study by Bell et al. (2009). Dembele et al. (2006) reported an association between lameness and poor animal care. This estimation of animal care included signs of careful attention to general problems in the cows and signs of poor attitude toward the cows. It is likely that farmers who pay close attention to indicators of problems in their herd are also more likely to treat cows promptly after identifying them as lame.

Less than half of the farmers were engaged in some form of proactive detection of lame cows. It is likely therefore that farmers are underestimating the prevalence of lameness on their farms, which is in agreement with Whay et al. (2002), who reported a gap between farmer-perceived lameness prevalence and lameness prevalence as recorded by a researcher. It may be assumed that lame cows on some farms have to wait for prolonged periods before they are identified as being lame and receive treatment for lameness. The association between proactive detection of lameness by the farmer and the prevalence of lameness was present in submodel 2 but not in the overall model. It was not clear which, if any, of the variables in the overall model confounded with this variable, causing its lack of significance.

On farms where the farmers had never seen cows with digital dermatitis, there was a lower prevalence of lameness in the overall model. In a study by Stokes et al. (2009), many cows with digital dermatitis did not score as lame unless they also had a claw horn lesion. It therefore appears likely that 1 or more intermediate factors are responsible for the association between lameness prevalence and digital dermatitis status on the farm rather than a direct association. One explanation is that digital dermatitis may complicate claw horn lesions and increase their severity. A second possible explanation is that the prevention and treatment of cows with digital dermatitis takes up valuable time that could be used for the treatment of lame cows. Alternatively, the farmers who have taken care to prevent digital dermatitis from infecting their farms are generally more aware of cow health and apply the same level of care to lameness and other cow health issues on their farms.

In the overall model there was confounding between the occurrence of severe heel erosion, interdigital growths, or toe necrosis in first-lactation heifers and 3 variables: damaged concrete, time to treatment, and length of time between the date cows were housed and the date of lameness scoring visit. In submodel 2 there was an increased prevalence of lameness on farms where the farmer responded that severe heel erosion, interdigital growths, or toe necrosis had been observed in first lactation-heifers. Although these lesions alone cause lameness, they may also act as a marker for failings in the herd health management. They could also act as a marker for an increased prevalence of digital dermatitis. Manske et al. (2002) reported an association between digital dermatitis, heel erosion, and interdigital growth. Anecdotal evidence suggests that toe necrosis is more common on farms with uncontrolled digital dermatitis. Further investigations of risk factors associated with specific types of lesions causing lameness are therefore required.

General factors associated with the farm system itself [breed, production type (i.e., organic or conventional), housing status at time of visit, herd size, and yield] that influence or are influenced by lameness were also tested in the models. There was a nonsignificant trend for the prevalence of lameness to be lower on organic farms than on conventional farms even with the inclusion of herd size in the submodel of management factors associated with lameness, which agrees with Rutherford et al. (2009). However, this trend is lost from the overall model. No single variable in the model appeared to have a strong confounding effect on the organic versus conventional management variable.

Having a herd consisting of a single breed other than Holstein-Friesian (e.g., Jersey or Ayrshire) or having a herd with a mixture of breeds and cross-breeds other than Holstein-Friesian was associated with reduced lameness. One explanation for the difference in lameness prevalence between Holstein-Friesian cows and cows of other breeds is the increased yields associated with the Holstein-Friesian breed. There was a small reduction in the coefficient for this variable with the inclusion of yield, but the association remained significant. This indicates that although yield varies between different breeds of cattle, breed remains an important variable in its own right. The smaller group size of this category should be taken into account when considering this variable. Alban (1995) reported lower risks for lameness associated with the Jersey breed compared with Danish Black and White, Danish Red and White, or Red Danish breeds. Baranski et al. (2008) also reported a significantly lower prevalence of lameness for Jersey cows compared with Holstein-Friesians.

In the overall model, farms where the milking cows had been housed for 61 d or longer at the time at which they were locomotion scored by the visiting researcher had a significantly higher prevalence of lameness than those where the cows had been housed for 0 to 60 d. This lag in the onset of lameness following housing may be a result of the time taken for many claw horn lesions to develop and become visible at the sole surface after damage occurring after entering the winter housing environment.

Despite being highly significant in the univariable analysis, average herd size was not significant in multivariable models, suggesting that much of the variation in lameness prevalence associated with herd size is accounted for by the model variables.

Mean annual milk yield per cow was used as a marker for the production level of the whole farm and any influence this might have on the environments in which the cows were kept and the way in which the cows were managed within those environments. The addition of milk yield to all of the models had the effect of reducing the overall significance of the models, suggesting that it is confounded by one or more of the model variables in each of the models. It is therefore not possible to draw conclusions on how the risks for lameness within different farm environments are affected by the production level of individual cows.

CONCLUSIONS

The high prevalence of lameness reported in this study should be of considerable concern to the dairy industry. The broad range in prevalence figures between farms demonstrates, however, that many farmers are successfully managing their cows to maintain minimal lameness in their herds. The analysis of the risks associated with lameness demonstrates that not only is it important to provide the cows with a suitable environment in which to live, it is essential to detect and treat lame cows promptly.

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