Herd-Level Risk Factors for Lameness in High-Producing Holstein Cows Housed in Freestall Barns

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ABSTRACT

The objective of this study was to investigate the association of some herd-level factors with the prevalence of lameness in 53 high-production groups of Holstein cows housed on 50 commercial dairy farms having freestall barns in Minnesota. Cows in the high-production group ($n = 5,626$) were scored for locomotion (score of 1 to 5, where 1 = normal and 5 = severely lame) to estimate prevalence of lameness (locomotion score ≥ 3) in the group. Herd-level variables were used to explain the variation in prevalence among groups. Among the variables tested, herd size, pen space per cow, type and size of milking parlor, total mixed ration content of crude protein and neutral detergent fiber, feeding frequency, linear feedbunk space per cow, type of feed barrier, and use of footbath did not show any association with the prevalence of lameness in the univariate analysis screening test and were not included in the multivariate model. Pen stocking density (cows per 100 stalls), total daily distance between pen and milking parlor, number of cows per full-time employee equivalent, cud chewing index, and pen type were eliminated from the multivariate model in the backwards stepwise procedure. Daily time away from the pen for milking was positively associated with the prevalence of lameness, whereas cow comfort quotient was negatively associated with prevalence of lameness. Prevalence of lameness was greater when farms performed hoof trimming only when the manager decided cows needed it because of hoof overgrowth or lameness compared with farms on which the feet of all cows were trimmed on a maintenance schedule once or twice annually. Brisket board height of more than 15.24 cm and presence of the area behind the brisket board filled with concrete were associated with greater prevalence of lameness. Most of these herd-level factors could be managed to reduce lameness prevalence in commercial dairy farms.

Key words: lameness, freestall, risk factor

INTRODUCTION

Lameness is one of the most important health, economic, and welfare problems in dairy farms today. Recent studies (Cook, 2003; Espejo et al., 2006) have indicated that approximately 25% of cows in commercial freestall dairies in the United States are lame at any one time. No milk price differential incentives exist to improve the lameness situation on dairy farms, but the economic and animal well-being consequences are becoming clearer. There has been increased interest to better monitor and prevent severe cases of lameness by using locomotion scoring systems. Locomotion scoring of dairy cattle evaluates certain walking behaviors and postures that are thought to be indicative of lameness (Sprecher et al., 1997). Use of locomotion scoring should help identify cows at earlier stages of lameness and result in faster recovery and reduced treatment costs.

Lameness has been recognized as a multifactorial condition. However, very few studies have investigated the association of on-farm herd-level risk factors with the prevalence of lameness, especially in freestall herds. The most recent study in Minnesota was published in 1995 and included 18 herds housed primarily in tie-stalls (Wells et al., 1995). In that study, factors such as stall moisture, size of the exercise area for lactating cows, and ration-balancing frequency were shown to be associated with prevalence of lameness. Current trends in the US dairy industry are for housing cows in freestall systems with concrete flooring. Research has indicated that exposure to concrete flooring can potentially increase the proportion of cows with claw disorders compared with other systems (Somers et al., 2003). Freestall barns have been shown to be more detrimental to hoof health than tie-stall barns (Cook, 2003). Factors associated with lameness in freestall herds would probably be different than in tie-stall systems. A recent study by Amory et al. (2006) on 19 farms and 1,450 cows in the Netherlands indicated that factors such as diet, presence of a footbath, and presence of a hoof trimming stall were associated with high locomotion scores. In that study, cows were housed in freestalls during the winter period. They were, however, on pasture during summer. Management systems differ

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among countries and the role of various herd-level risk factors therefore remains unclear. There is a need to study the relationship between lameness prevalence and on-farm risk factors in freestall herds in North America.

Conclusions from experimental studies may not be applicable to commercial farms because treatment levels used in experimental studies might not always be present in field situations. In addition, on commercial farms, there are in many complex interactions between factors that could affect the estimation of associations. Field research investigating large numbers of cows and herds has been limited. In addition, most studies have used herds that were not randomly selected.

The objective of this study was to investigate the association of herd-level factors with the prevalence of lameness in high-producing Holstein cows housed in 50 randomly selected dairy farms having freestall barns in Minnesota.

MATERIALS AND METHODS

This study was performed in 50 freestall farms in Minnesota between June and October 2004. Dairy farms were selected randomly from the total population of herds having more than 150 cows situated within a geographical area where most of the dairy farms in Minnesota are located. All farms had Holstein cows as the predominant breed. No previous knowledge existed about the prevalence of lameness in these farms or their management protocols. These selected farms had on average 474 ± 321 (mean $\pm$ SD) cows and milk production averaged 32.9 ± 5.4 kg of FCM per cow per day. Therefore, results from this study would represent the population of cows in the high-production group housed in freestall dairy farms with a herd size ≥ 150 cows. A more detailed description of herd selection and characteristics can be found in a previous publication on prevalence of lameness in freestall barns (Espejo et al., 2006).

All dairies were visited once during the study period. Data were collected using direct observation of the cows and their environment, interview with the herd manager during the visit, feed sampling and analysis, and compilation of herd records. In each farm, data were collected from what producers called the high-production group on the farm. On 3 farms, we studied 2 high-production groups instead of one, because herd managers considered both groups as high-production groups and there were differences in stall design, flooring type, and other variables between the 2 groups. Therefore, we analyzed a total of 53 high-production groups from 50 farms. Group size averaged 117 ± 51 cows. A total of 5,626 cows were included in the study. There were

16 high-production groups out of the total of 53 groups in the study that did not include first-lactation cows. High-production group cows (as defined by the herd manager) housed in the hospital pen during the visit also were included in the study. All non-Holstein cows in the groups were excluded from the study. In the herds visited in this study, cows were housed in the high-production pen mostly because of their milk production and not necessarily their DIM. Approximately 49% of the cows included in the study were more than 150 DIM. On average, 97.2% of the cows housed in the high-production groups were used in this study.

Cows were evaluated for lameness using the 5-point locomotion scoring (LS) system (Sprecher et al., 1997), using additional observations suggested by O'Callaghan et al. (2003), where 1 = normal locomotion, 2 = imperfect locomotion, 3 = lame, 4 = moderately to severely lame, and 5 = severely lame. Clinical case of lameness was indicated by a $LS \geq 3$. Additional observations included tracking (hind feet on fore feet position), head bob (extent of movement and level of bobbing), and whether feet point in the direction of travel. Locomotion scoring was performed by an experienced observer at the exit of the milking parlor after the afternoon milking. Prevalence of clinical lameness in the groups was calculated as a proportion of cows affected during the visit. Prevalence of lameness averaged 24.6%. Prevalence of lameness results were presented in more detail in a previous article (Espejo et al., 2006).

Herd size was obtained from the interview with the herd manager and from the nearest DHIA test records. Similarly, data about feeding frequency and number of cows per full-time employee equivalent (FTE, 50 h/wk) were obtained from the interview with the herd manager. Two indicators of the high-production pen stocking density were calculated. One was calculated as the number of cows in the high-production pen ($\times 100$) divided by the total number of available stalls in that pen (cows per 100 stalls). The other was calculated as the total area of the high production pen (i.e., including stalls, alleys, and crossovers) divided by the number of cows in that pen (pen space per cow). Milking parlor type (flat, herringbone, parallel, or rotary), milking parlor size (number of milking units), pen type (2-row or 3-row configuration), linear feedbunk space per cow (m/cow), type of feed barrier (headlocks or post-and-rail), brisket board height, and whether the area behind the brisket board was filled with concrete or not (at the same level as the brisket board) were recorded during the visit. Height of the brisket board was measured perpendicularly to the surface of the stall. Analysis of the distribution of this variable showed that its association with prevalence of lameness could be evaluated using 2 categories: 1 for brisket board heights ≤ 15.2 cm

and 2 for those >15.2 cm. Other stall measurements, such as stall width, total stall length (facing wall and facing stall), stall length from rear curb to brisket board, height below neck rail, height of rear curb, height of lower divider rail, stall opening, horizontal distance between rear curb, and neck rail, were also measured, but not used in the analysis due to lack of variation and sufficient replication between farms. Association between stall surface (mattress or sand) and prevalence of lameness was documented in a previous article (Espejo et al., 2006).

Use of footbath was evaluated using the following scores: 0 for those farms that did not use footbaths regularly or did not use them at all, and 1 for those farms that used footbaths regularly (twice weekly or more). In general, the product used in footbaths was copper sulfate (sometimes rotated with zinc sulfate), with the exception of 2 farms that used formaldehyde. Frequency of hoof trimming was evaluated on a 3-point scale according to the answer of the managers, where 1 was "only when the cows need it" (i.e., cows selected by the manager for trimming because of hoof overgrowth or lameness), 2 was "once annually (usually at dry off) plus when the cows need it," and 3 was "twice annually (usually at dry off and mid-lactation) plus when the cows need it".

Observations of cow comfort and rumination behavior were performed randomly by a trained observer every 1.5 to 2.5 h during the farm visit (average of 5 observations per herd), to calculate the cow comfort quotient (CCQ). The CCQ was the number of cows that were lying properly in stalls ($\times 100$) divided by the number of cows that were touching a stall (lying or standing with 2 or 4 feet in the stall). The cud chewing index (CCI) was the number of cows that were lying down in stalls and ruminating $\times 100$ divided by the total number of cows lying down (Nelson, 1996). Average of these 5 observations of CCQ and CCI was calculated for each high-production group. It is important to note that the CCQ does not take into account cows that are standing in the alley or at the feed bunk. Therefore, CCQ would be a crude assessment of the comfort of the stalls, rather than a measurement of the proportion of cows lying down as a percentage of total cows in a pen at any given time. We used the CCQ because it is an index commonly used by consultants to assess stall comfort. To our knowledge, no studies are available to date that investigated the association between this on-farm index and prevalence of lameness.

Measurements of the distance between the pen in which cows were housed and the milking parlor were recorded. That distance was multiplied by 2 times the number of milkings per day, to calculate the total mandatory distance that cows walked before and after milk-

ing per day. Total time that cows were away from the pen for milking was calculated multiplying the number of milkings per day by the time (min) that cows spent from the moment they left the pen to go to the milking parlor until the moment when all cows returned to the pen.

On each farm, samples of the TMR as delivered to the cows were collected from 6 to 10 areas across the feed bunk of the high-group pen. These samples were mixed together and a composite sample was taken for chemical analysis. Each composite sample was analyzed for CP and NDF using standard methods. Samples were dried in a 60°C forced-air oven and ground in a Wiley mill (Swedesboro, NJ) to pass through a 1-mm screen. Final DM was determined by drying samples at a 105°C for 8 h (AOAC, 1995). Samples were analyzed for NDF using the Ankom²⁰⁰ fiber system (Ankom Technology Corporation, Fairport, NY). Sodium sulfite and heat-stable α -amylase were included in the neutral detergent extraction, and heat-stable α -amylase was also added during the first 2 rinses (Hintz et al., 1996). Samples were analyzed for CP using a TrueSpec Protein Nitrogen Analyzer (Leco Corporation, St. Joseph, MI; AOAC, 1995).

Statistical Analyses

Association between each variable and prevalence of lameness per group was evaluated with a univariate model as a screening test, using a mixed model procedure (PROC MIXED; SAS Institute Inc., Cary, NC). Farm was used as a random variable in the analysis. Because information was collected from 2 groups in 3 of the farms, the analysis included an adjustment using group nested within farm. Those variables identified in the univariate screening test ($P < 0.3$) were used to build a multivariate model using a mixed model procedure (SAS Institute Inc.). In the multivariate model, variables that showed less association with the prevalence of lameness were eliminated using a backwards stepwise procedure until all the remaining variables included in the multivariate model were significant ($P < 0.05$). The assumption of random distribution of the residuals was visually evaluated on a residual chart for the final model. Bonferroni contrast t -test was used to compare least squares means of categorically distributed variables.

RESULTS AND DISCUSSION

Univariate Screening Test

Tables 1 and 2 show the distribution of the variables analyzed in this study, including overall frequency and

Table 1. Distribution of the quantitative variables for 53 high-producing groups of Holstein cows housed in freestall dairy farms in Minnesota

Variable	Overall		25th percentile ¹	
	Mean	SD	Low	High
Herd size	474	321	407	396
High-production group stocking density, cows/100 stalls	109	13.1	112	108
High-production group stocking density, m ² /cow	6.4	1.3	6.3	6.5
Distance: pen to milking parlor, m/d	254	258	370	198
Time away from pen, min/d	244	78	256	282
Linear feedbunk space, m/cow	0.45	0.11	0.47	0.45
Number of cows per FTE equivalent ²	50.0	12.7	46.5	55.8
Ration CP content, %	17.5	1.0	17.3	17.6
Ration NDF content, %	30.6	2.3	30.6	31.0
Milking parlor size, number of milking units	20.7	8.5	21.1	16.9
Cow comfort quotient, %	76.0	9.5	80.8	73.4
Cud chewing index, %	35.6	7.7	38.0	33.5

¹Means calculated on basis of low and high 25th percentiles for lameness prevalence.²FTE = Full time employee (50 h/wk).

means and frequency for the low and high 25th percentiles for prevalence of lameness. The univariate analysis of association between each variable and prevalence of lameness in the group (Table 3) showed that herd size, pen space per cow, milking parlor type, milking

parlor size, CP and NDF contents of TMR, feeding frequency, linear feedbunk space per cow, type of feed barrier, and use of footbath were unrelated ($P > 0.3$). Therefore, these variables were not included in the multivariate model.

Table 2. Distribution of the qualitative variables for 53 high-producing groups of Holstein cows housed in freestall dairy farms in Minnesota

Variable	Overall frequency	25th percentile ¹	
		Low	High
Hoof trimming frequency			
When cows need it	15.1	0	30.8
Once annually plus when cows need it	43.4	38.5	30.8
Twice annually plus when cows need it	41.5	61.5	38.4
Presence and use of footbath			
Yes	67.9	61.5	61.5
No	32.1	38.5	38.5
Feeding frequency			
Once a day	62.3	76.9	46.1
Twice a day	30.2	7.7	46.1
Three times a day	7.5	15.4	7.8
Type of feed barrier			
Headlock	32.1	46.2	30.8
Post-and-rail	67.9	53.8	69.2
Milking parlor type			
Flat	11.3	15.4	15.4
Herringbone	37.7	30.8	15.4
Parallel	47.2	53.8	69.2
Rotary	3.8	0	0
Pen type			
2-row	35.8	46.2	15.4
3-row	64.2	53.8	84.6
Brisket board height			
≤15.24 cm	32.1	46.2	7.7
>15.24 cm	67.9	53.8	92.3
Area behind brisket board filled with concrete?			
Yes	45.3	30.8	69.2
No	54.7	69.2	30.8

¹Frequencies calculated in basis of low and high 25th percentiles for lameness prevalence.

Table 3. Univariate regression analysis probability values between prevalence of lameness and herd-level variables in 53 high-producing groups of Holstein cows housed in freestall dairy farms in Minnesota

Variable	P-value
Herd size	0.68
High production group stocking density, cows/100 stalls	0.19
High production group stocking density, m ² /cow	0.45
Distance: pen to milking parlor, m/d	0.12
Time away from pen, min/d	0.27
Number of cows per FTE equivalent ¹	0.17
Linear feed bunk space, m/cow	0.42
Type of feed barrier	0.72
Ration CP content, %	0.36
Ration NDF content, %	0.66
Milking parlor size, number of milking units	0.38
Cow comfort quotient, %	<0.01
Cud chewing index, %	0.04
Hoof trimming frequency	0.01
Presence and use of footbath	0.80
Feeding frequency	0.31
Milking parlor type	0.48
Pen type	0.08
Brisket board height	<0.01
Area behind brisket board filled with concrete	0.06

¹FTE = Full time employee (50 h/wk).

Herd size did not show an association with the prevalence of lameness. A limited number of studies performed outside North America using on-farm records rather than lameness prevalence reported different results. In a survey of 340 herds in southern England, Whitaker et al. (2000) found evidence that larger herds had more lameness problems, and Alban (1995) found that cows in herds having more than 124 cows had a 4 times greater risk for lameness than cows in herds between 20 and 30 cows. Alban (1995) suggested that as a consequence of the use of more mechanization and less labor in large herds, the time that farmers spend with their cows is reduced, which could limit the chance to identify and treat lame cows. These 2 studies were performed in herds with diverse use of technology, mechanization, and labor, and included small herds. The current study included only freestall herds with more than 150 cows in which differences in the use of mechanization and technology among farms of different herd sizes should not be an important source of variation.

Milking parlor type and size were not associated with prevalence of lameness in the group. The reason to investigate this association was the hypothesis that the position and movements that cows must make to be milked could be a mechanical stress to the hooves. When cows enter into a parallel milking parlor, they have to make a sharp turn in a short space to assume the milking position for this type of parlor. This turn is less sharp in herringbone milking parlors, which could result in less stress to the hooves. In addition, in flat

milking parlors, cows have to make a step up to assume the milking position. Even though height or number of steps varied within this type of milking parlor, steps represent a change in the weight distribution of the feet. Milking parlor size could affect milking efficiency and the time that cows must wait standing to be milked, depending on group size.

Contents of CP and NDF in the TMR were not associated with prevalence of lameness in the current study. The study was performed on commercial dairy farms and the nutrient content of the rations was near the recommended levels for high-producing cows. The CP of the rations investigated in this study averaged 17.5%. Studies that associated dietary protein content with lameness problems reported greater concentration of crude protein (e.g., 19%; Manson and Leaver, 1988). In addition, the NDF content of the diet averaged 30.6%, which is within recommended levels.

Use of a footbath was not associated with the prevalence of lameness. Arkins (1981) reported a positive effect of footbath use on the incidence of lameness; however, some studies found a negative effect on lameness (Chesterton et al., 1989; Amory et al., 2006). These discrepancies could be related to the type of lesions that originated the lameness or the effective use or not of footbaths. On-farm records on types of foot lesions were not readily available from the herds visited in the current study. From the interview with herd managers or hoof trimmers, it seemed that the majority of foot problems observed in these herds were sole ulcers. Further studies that also determine the underlying disease resulting in lameness should be conducted. Chesterton et al. (1989) mentioned that farms having greater prevalence of lameness are more likely to use footbaths, which makes it more difficult for the detection of their potential beneficial effect. It is also possible that the baseline for footbath use described in the current study (at least twice weekly) was too small to detect an association between this variable and prevalence of lameness. Because of a low variation in the product used in the footbath (only 2 farms used formaldehyde and the remaining farms used copper sulfate), an analysis of association between the product used in the footbath and the prevalence of lameness was not possible.

In this study, the stocking density measured as pen space per cow averaged 6.4 ± 1.3 m². This variable was considered in this study because under confinement conditions subordinate cows have less space to avoid confrontations with cows of greater hierarchy, which could induce foot lesions. Amount of pen space per cow found in this study did not show an association with the prevalence of lameness, at least for the average cow in the herd. Similarly, linear feedbunk space per cow (0.45 ± 0.11 m) and type of feed barrier (68% of groups

had post-and-rail; 32% had headlocks) were not associated with the prevalence of lameness.

Multivariate Model

Pen stocking density, measured as cows per 100 stalls, distance between pen and milking parlor, time away from the pen, number of cows per FTE, CCQ, CCI, hoof trimming frequency, pen type, brisket board height, and area behind brisket board filled with concrete were eligible for inclusion in the multivariate model. Stocking density, measured as cows per 100 stalls, distance between pen and milking parlor, pen type, number of cows per FTE, and CCI, however, were eliminated from the final model in the backwards stepwise procedure.

Overcrowding could affect lying times and consequently affect lameness prevalence. Wierenga and Hopster (1990) reported reduced lying time of 54.7% for cows in freestalls housed at a 155% stocking rate (i.e., 155 cows per 100 stalls) compared with a normal stocking rate (100%). In another experiment reported in the same article, cows at 125% stocking rate had no significant reduction in lying time; however, standing time in the walking area increased by 53.8% and standing time in stalls increased by 43.8%. Stocking density, measured as cows per 100 stalls, observed in the current study averaged 109% and ranged from 77 to 146%. Even though 3 farms had stocking densities greater than 130% (2 with 138% and 1 with 146%), it is possible that those farms compensated for this overcrowding level with a more intensive management for foot health, which could have minimized the effect of overcrowding. As for the pen space per cow, the current study did not evaluate the effect of stall overcrowding on individual cows, which could have been different for more submissive cows than for the average cow in the group.

Walking distances for cows have been associated with lameness in cows on pasture in Australia, where interdigital cracking and pain were more common when the track length was shorter. The reason for this finding was suggested to be that in shorter tracks there is an increase on the crowding conditions (more cows tend to pass through the same place at the same moment), which reduces the choice of foot placement (Harris et al., 1988). In addition, constant twisting and turning could cause mechanical stress on the hooves (Bazeley and Pinsent, 1984). In contrast, in New Zealand, long walking distances have been associated with laminitis because excess exercise on hard surfaces can cause mechanical stress on the hooves (Vermunt, 1992). These studies were performed with cows on pasture where normally the walking distances to be milked are longer and the maintenance of the walking lanes represents

a source of variation between farms. In this study, the total mandatory distance that cows walked to be milked was on average 253.7 m/d on a grooved concrete surface that was mostly similar among farms.

Number of cows per FTE averaged 50 and this variable was not associated with the prevalence of lameness. The opportunity to detect lame cows could be better when farm workers can pay more attention to fewer cows, potentially being able to identify earlier stages of lameness. Distribution of the work on farms did not always include detection of hoof or leg problems as a regular management practice.

Nelson (1996) defined CCI as a crude measure to evaluate the amount of physically effective fiber in the diet. He suggested that this index should be greater than 40 to 50% to consider that the herd is receiving an adequate amount of effective fiber. In the current study CCI ranged from 17.9 to 54.4%, with an average of 36.1%. Cows in this randomly selected population of freestall herds on average were not reaching the goal suggested by Nelson (1996). Herds in the top quartile averaged 41%; therefore, meeting only the minimum suggested level. This index is not easily recorded, because cows can stop rumination at any sign of movement in the barn. Although the observer was very careful to move around quietly, some underestimation of this index may have occurred. The manner in which the index was measured, however, represented typical practice by consultants in the field and the goal of the study was to investigate practical on-farm measurements. Other authors suggested that rumination is a sign of relaxation in cattle and that ruminating activity decreases when cows are stressed (Phillips, 2002). Therefore, CCI could also be related to cow comfort. In this study, CCI was eliminated from the model in the stepwise procedure.

Most of the cows (64.2%) were housed in 3-row configuration barns, which provided more limited feeding space per cow compared with 2-row barns. This limitation could affect access to feed, a situation that could be enhanced by overcrowding conditions in the pen. In our study, however, association between pen type and prevalence of lameness was eliminated from the final model in the stepwise procedure.

Final Model

Variables included in the final model were time away from the pen, CCQ, frequency of hoof trimming, height of the brisket board, and area behind brisket board filled with concrete (Table 4). No specific trend was visualized in the residual chart. Results of the Bonferroni contrast *t*-test for categorically distributed variables are included in Table 5.

Table 4. Herd-level variables and their association with the prevalence of lameness in 53 high-producing groups of Holstein cows housed in freestall dairy farms in Minnesota

Variable	Coefficient	SE	P-value
Time away from pen, min	0.04	0.02	0.02
Cow comfort quotient, %	-0.34	0.14	0.02
Hoof trimming frequency			
When cows need it	12.38	4.06	<0.01
Once annually plus when cows need it	1.71	2.86	0.55
Twice annually plus when cows need it	0	0	—
Brisket board height			
≤15.2 cm	-5.67	2.90	0.05
>15.2 cm	0	0	—
Area behind brisket board filled with concrete?			
No	-5.25	2.67	0.05
Yes	0	0	—

Daily time that cows spent outside the pen during milking was associated with the prevalence of lameness ($P < 0.05$). The top quartile groups averaged 160 min away from the pen, whereas the bottom quartile groups averaged 351 min. Average prevalence of lameness for these groups was 21.2 and 26.5%, respectively. At milking time, cows did not have the opportunity to lie down, and in most cases, they did not have access to feed or water either. Average time that cows spent without access to the stalls in the current study was 4.1 h/d, which is greater than the values of 2.6 to 3.2 h/d reported by Cook et al. (2004). It is possible that the extra time that cows spent outside of the pen negatively affected their resting time budget. Metz (1985) observed that cows with short-term deprivation (3 h per morning) of lying time changed their time budget in hours following deprivation and demonstrated a strong need for lying. Time budget changes could affect hoof health (Cook et al., 2004).

Table 5. Lameness prevalence least squares means of qualitative factors associated with the prevalence of lameness in 53 high-producing groups of Holstein cows housed in freestall dairy farms in Minnesota

Variable	Least squares mean
Hoof trimming	
When cows need it	33.7 ^a
Once annually plus when cows need it	22.9 ^b
Twice annually plus when cows need it	21.3 ^b
Brisket board height	
≤15.2 cm	23.1 ^a
>15.2 cm	28.8 ^b
Area behind brisket board filled with concrete?	
No	23.3 ^a
Yes	28.6 ^b

^{a,b}Means within variable having different superscript letters differ ($P < 0.05$) according to the Bonferroni *t*-test.

The CCQ was negatively associated ($P < 0.05$) with the prevalence of lameness in the high-production groups, and it averaged 76% across groups in our study. Cook et al. (2005) reported CCQ (described therein as cow comfort index) least squares means of 76% for high-production cows housed in freestall barns having mattress bases and 86% for cows housed on a sand base. These results were slightly greater than the current study, but within the same range. Nelson (1996) defined CCQ as a crude evaluation of the stall and bedding comfort and recommended that CCQ should be at least 80%, with well-managed herds at 85% or more at any time of the day. The minimum recorded group average CCQ in the current study was 52% and the maximum was 92%, with the top and bottom quartile groups averaging 87.5 and 63%, respectively. This indicates that the goal of 85% can be achieved in well-managed herds that have comfortable stalls. Average lameness prevalence in the CCQ top quartile groups was 18.7%, whereas in the bottom quartile groups it was 33.7%.

Consultants in the field have used this index of cow comfort and it is encouraging to learn that it was associated with prevalence of lameness in this study of randomly selected freestall herds. This measurement could also be performed by the herd manager to assess comfort of stalls. A smaller CCQ would indicate that cows are at a greater risk for lameness and would be an incentive for the manager or consultant to evaluate and possibly improve stall design. Cook et al. (2005) recently recommended the use of the stall standing index (SSI, proportion of cows touching a stall that are standing either with 2 or 4 feet in the stall), the reciprocal of CCQ (or cow comfort index), measured 2 h before the morning or afternoon milking. Authors indicated that values greater than 20% would be associated with longer stall standing times. In the current study, a relationship was found between CCQ (the reciprocal of SSI) and prevalence of lameness, which further sub-

stantiates the recommendation of SSI less than 20%. Cook et al. (2005) also suggested that CCQ would be less in those farms with lameness problems and poorly designed freestalls.

Cows with untrimmed hooves have more lameness problems, and it has been demonstrated that hoof trimming can help reduce incidence of lameness and claw lesions (Manson and Leaver, 1988; Faye and Lescourret, 1989). Researchers have indicated that hoof trimming has a combination of effects on the claw—a therapeutic effect in the case of lesions and a prophylactic effect preventing lesions (Shearer and van Amstel, 2001; Manske et al., 2002). The current study found an association ($P < 0.01$) between the frequency of hoof trimming and the prevalence of lameness. The analysis of the least squares means for the hoof trimming frequency indicated that those farms that practiced hoof trimming on a regular basis (once or twice annually and when cows need it) for the prophylactic and therapeutic effect had less prevalence of lameness than those farms that practiced hoof trimming only for the therapeutic effect (when the cows need it). Based on questionnaire responses, most dairies (with the exception of 1 dairy) considered their hoof trimmer to be well trained and using appropriate technique.

Previous research reported conflicting results related to the frequency of hoof trimming. Manson and Leaver (1988) indicated that hoof trimming should be performed at least once annually, and Manske et al. (2002) suggested performing hoof trimming at least twice annually. In contrast, Faye and Lescourret (1989) mentioned that the total frequency of foot diseases increased when hoof trimming was performed more than once annually. Manske et al. (2002) concluded that the optimal frequency of claw trimming should be determined by specific factors on each farm and each cow. We did not find differences in prevalence of lameness between those farms that practiced maintenance hoof trimming once or twice annually (Table 5). It is important to keep in mind that over-trimming hooves or not using appropriate hoof trimming technique can also contribute to the development of lameness.

Brisket board height was associated ($P < 0.05$) with the prevalence of lameness. Least squares means of the prevalence of lameness for brisket board height showed a difference between ≤ 15.2 cm and > 15.2 cm (23.1 and 28.8%, respectively). It has been recommended that brisket board height be < 15.2 cm and preferably be limited to 10.2 cm above the stall surface to allow more natural lunging and rising behavior in dairy cows (Nordlund and Cook, 2003).

Presence of an area behind the brisket board filled with concrete also was associated ($P < 0.05$) with prevalence of lameness. Least squares means of the preva-

lence of lameness for this variable (Table 5) showed a greater prevalence of lameness in the group of cows using stalls with area behind the brisket board filled with concrete compared with those without this stall feature (28.6 and 23.3%, respectively). The brisket board and the area behind the brisket board filled with concrete represent obstructions for normal cow rising behavior. These obstructions could have a negative impact on use of stalls and the lying down time. Cows put forward one of their front legs when they rise. The presence of concrete behind the brisket board makes the process of rising more difficult for the cows, because the surface where cows put their front leg when getting up is higher than the stall surface. This factor could reduce use of stalls and increase the pressure that the hooves must bear when cows rise from the stall.

CONCLUSIONS

The objective of this cross-sectional study was to investigate the association between on-farm herd-level variables and prevalence of lameness. Results indicate that under the commercial conditions investigated in this study, the time that cows spend away from their pen during milking, comfort of the stalls, hoof trimming frequency, height of the brisket board, and presence of an area behind the brisket board filled with concrete were associated with the prevalence of lameness in the high-production group of cows. Most of these herd-level factors could be managed to reduce prevalence of lameness in commercial dairy farms.

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REFERENCES

- Alban, L. 1995. Lameness in Danish dairy cows: Frequency and possible risk factors. *Prev. Vet. Med.* 22:213–225.
- Amory, J. R., P. Kloosterman, Z. E. Barker, J. L. Wright, R. W. Blowey, and L. E. Green. 2006. Risk factors for reduced locomotion in dairy cattle on nineteen farms in the Netherlands. *J. Dairy Sci.* 89:1509–1515.
- AOAC. 1995. *Official Methods of Analysis*. 16th ed. Association of Official Analytical Chemists, Arlington, VA.
- Arkins, S. 1981. Lameness in dairy cows. *Irish Vet. J.* 35:163–170.
- Bazeley, K., and P. J. Pinsent. 1984. Preliminary observations on a series of outbreaks of acute laminitis in dairy cattle. *Vet. Rec.* 115:619–622.
- Chesterton, R. N., D. U. Pfeiffer, R. S. Morris, and C. M. Tanner. 1989. Environmental and behavioural factors affecting the prevalence of foot lameness in New Zealand dairy herds—A case-control study. *N.Z. Vet. J.* 37:135–142.
- Cook, N. B. 2003. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. *J. Am. Vet. Med. Assoc.* 223:1324–1328.

- Cook, N. B., T. B. Bennett, and K. V. Nordlund. 2004. Effect of freestall surface on daily activity patterns in dairy cows with relevance to lameness prevalence. *J. Dairy Sci.* 87:2912–2922.
- Cook, N. B., T. B. Bennett, and K. V. Nordlund. 2005. Monitoring indices of cow comfort in free-stalls-housed dairy herds. *J. Dairy Sci.* 88:3876–3885.
- Espejo, L. A., M. I. Endres, and J. A. Salfer. 2006. Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. *J. Dairy Sci.* 89:3052–3058.
- Faye, B., and F. Lescourret. 1989. Environmental factors associated with lameness in dairy cattle. *Prev. Vet. Med.* 7:267–287.
- Harris, D. J., C. D. Hibburt, G. A. Anderson, P. J. Younis, D. H. Fitzpatrick, A. C. Dunn, I. W. Parsons, and N. R. McBeath. 1988. The incidence, cost and factors associated with foot lameness in dairy cattle in southwestern Victoria. *Aust. Vet. J.* 65:171–176.
- Hintz, R. W., D. R. Mertens, and K. A. Albrecht. 1996. Effects of sodium sulfite on recovery and composition of detergent fiber and lignin. *J. AOAC Int.* 79:16–22.
- Manske, T., J. Hultgren, and C. Bergsten. 2002. The effect of claw trimming on the hoof health of Swedish dairy cattle. *Prev. Vet. Med.* 54:113–129.
- Manson, F. J., and J. D. Leaver. 1988. The influence of dietary protein intake and of hoof trimming on lameness in dairy cattle. *Anim. Prod.* 47:191–199.
- Metz, J. H. M. 1985. The reaction of cows to short term deprivation of lying. *Appl. Anim. Behav. Sci.* 13:301–307.
- Nelson, A. J. 1996. On-farm nutrition diagnostics: Nutrition management involvement opportunities for dairy practitioners. Page 76 in *Proc. 29th Annu. Conv. Am. Assoc. Bovine Pract.*, San Diego, CA.
- Nordlund, K., and N. B. Cook. 2003. A flowchart for evaluating dairy cow freestalls. *Bovine Pract.* 37:89–96.
- O'Callaghan, K. A., P. J. Cripps, D. Y. Downham, and R. D. Murray. 2003. Subjective and objective assessment of pain and discomfort due to lameness in dairy cattle. Page 605 in *Proc. 2nd Intl. Workshop on the Assessment of Animal Welfare at Farm and Group Level*, University of Bristol, UK. Univ. Fed. Anim. Welf., Herts, UK.
- Phillips, C. 2002. *Cattle Behaviour and Welfare*. 2nd ed. Blackwell Science Ltd, Oxford, UK.
- Shearer, J. K., and S. R. van Amstel. 2001. Functional and corrective claw trimming. *Vet. Clin. North Am. Food Anim. Pract.* 17:53–72.
- Somers, J. G. C. J., K. Frankena, E. N. Noordhuizen-Stassen, and J. H. M. Metz. 2003. Prevalence of claw disorders in Dutch dairy cows exposed to several floor systems. *J. Dairy Sci.* 86:2082–2093.
- Sprecher, D. J., D. E. Hostetler, and J. B. Kaneene. 1997. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. *Theriogenology* 47:1179–1187.
- Vermunt, J. J. 1992. Subclinical laminitis in dairy cattle. *N.Z. Vet. J.* 40:133–138.
- Wells, S. J., A. M. Trent, W. E. Marsh, N. B. Williamson, and R. A. Robinson. 1995. Some risk factors associated with clinical lameness in dairy herds in Minnesota and Wisconsin. *Vet. Rec.* 136:537–540.
- Whitaker, D. A., J. M. Kelly, and S. Smith. 2000. Disposal and disease rates in 340 British dairy herds. *Vet. Rec.* 146:363–367.
- Wierenga, H. K., and H. Hopster. 1990. The significance of cubicles for the behaviour of dairy cows. *Appl. Anim. Behav. Sci.* 26:309–337.